# HEMISPHERIC ORGANIZATION IN THE DEAF: A COMPARATIVE STUDY

BY

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Recent research has focused on the hemispheric organization of the deaf, and particularly their lateral organization for language, in hopes of understanding how laterality develops. This research, however, has been confounded by methodological and sampling errors and has failed to control for early language training. The present research attempted to compare hemispheric organization of individuals in a Hearing group (10 males, 10 females), an Oral group (10 males, 10 females), and a Sign group (9 males, 9 females) on four separate tasks: tactile exploration of shapes and line orientations and tachistoscopic presentation of American Sign Language (ASL) handshapes and non-ASL handshapes.

Results of the experiment demonstrated no predicted field x group interaction. Instead, all groups appeared to use similar processing strategies for the tasks. What was observed, however, was differential effects for laterality dependent upon sex, side of stimuli input, and side of response output. Specifically, for lines and shapes, males responded initially with a right hemisphere, visuospatial strategy, but switched to a left hemisphere, verbal strategy with practice. Females, who initially preferred a verbal strategy and performed poorly with right hemisphere processing, were able to improve with the right hemisphere with practice. For the ASL handshapes, no visual half-field effects were found. The Sign group, however, was more accurate than the Oral, who were more accurate than the Hearing. This finding both validates the composition of the deaf groups and suggests that early language training does affect the later accuracy with which the deaf groups process signs. Finally, all three groups demonstrated a right hemisphere advantage for the non-ASL handshapes, with both deaf groups being significantly more accurate than the Hearing.

It appears that in terms of the way the brain is organized for certain tasks, it matters more whether one is male or female than whether one is deaf or hearing. Also, no task is inherently a left or right hemisphere task, and hemispheric processing may be manipulated depending on the demands of the task. Finally, it is important to consider both

hemispheric input and output when investigating differences in hemispheric organization as these interact with gender to determine laterality differences.

# CHAPTER I
# INTRODUCTION AND LITERATURE REVIEW

One prominent focus of investigation within the past few years has been on understanding the presence and development of cerebral lateralization in man. It now appears that most normal, right-handed hearing individuals are lateralized for language in the left hemisphere (along with analytic and sequential processing in general), while the right hemisphere is reserved for tasks requiring spatial, holistic and parallel processing (Bever & Chiarello, 1974; Ross, Pergament, & Anisfeld, 1979). (Lateralization of left handed individuals is a much different and more complicated story.) Before the use of tachistoscopes in visual half-field experiments, much of our knowledge of the laterality of language and other processes was based on work with patients suffering from unilateral brain lesions. With this population, it was difficult to determine what impairments in ability were due to the absence of necessary cortical areas (which would document laterality) or were due to misconnections formed in the recovery of the brain to the lesion. Use of the tachistoscope in visual half-field experiments has allowed us to investigate laterality in the normal, non-lesioned brain. This research in visual half-field processing has shown a consistent left hemisphere advantage

(LHA) for language (printed words, letters) and a right hemisphere advantage (RHA) for spatial material (complex shapes, faces, line orientations). What this research has not shown, however, is why the human brain lateralizes as it does, i.e., how laterality develops. Different hypotheses have been proposed to account for the development of the lateral organization in the brain (McKeever, Hoemann, Florian, & Van Deventer, 1976; Scholes & Fischler, 1979), but the area remains controversial because of the issues of handedness (Levy, 1969; Levy, 1974) and processing strategies (Bever, 1975).

A processing strategy that has been thought by some to impact on the lateralization of the brain, particularly as it relates to language, is auditory processing. Researchers have suggested that the left hemisphere handles all auditory input, and thus language, while the right hemisphere is responsible for visual stimuli, thereby explaining the RHA that has been found for complex shapes, faces and line orientations. Another line of thought suggests that the left hemisphere is not specialized solely for language processing or auditory input, but more specifically for analytic processing. In turn, the right hemisphere deals most effectively with holistic processing regardless of the modality of the input (Bever, Hurtig, & Handel, 1976; Nebes, 1974). From this argument it would follow that it is not the auditory nature of language that places it in the left hemisphere,

or the fact that it is language per se. Rather, the important variable then becomes the type of processing involved in the use of language.

One means of assessing the impact of auditory processing in the development of laterality of language is the study of cerebral lateralization in the congenitally deaf individual. This population allows the researcher to investigate the development of laterality in the absence of auditory input. In addition, many of these individuals utilize a sign language which is different from English. This sign language, known as American Sign Language (ASL), has its own distinct syntax, lexical structure and sublexical structure which are different from the oral phonology of the English language (Woodward, 1977). It also differs from other types of manual communication such as finger spelling or Signed English (a visual form of English) at the syntactic, morphological and phonological level. Finger spelling assigns 26 distinct hand configurations to the separate letters of the English alphabet and is used to spell out English words and sentences in the air, letter by letter. Therefore, finger spelling does not differ in structure from English. In contrast, Signed English on the surface seems more similar to ASL in that it uses similar signs, but these signs are put in the order of English syntax. Both finger spelling and Signed English are difficult for the deaf person to understand (unless he/she is very familiar with English)

and more likely represent a second language to the deaf person, distinct from ASL. Given these differences in manual communication, it is important to note that research in the hemispheric specialization of the deaf has generally failed to make any distinctions between finger spelling, visual English, and ASL when describing or investigating manual communication.

Before one can hypothesize differences in laterality between ASL and English, one needs to understand something of the structure of ASL. The syntax of ASL can best be described as telegraphic, often with action words and nouns occurring first, with few connecting units. Not only the signs themselves, but their movements and their speed of movement, along with the body gestures and facial expressions of the signer, are integral components of the syntax. In fact, it is difficult to give meaning to a sign in ASL without associated movements and gestures. Because of this, ASL would seem to lend itself best to a holistic, spatial processing which is different from the analytic processing required to handle English syntax, and ASL, therefore, may be handled most efficiently by the right hemisphere. As noted earlier, it has become a given in laterality research that language (in right handed hearing individuals) is controlled by the left hemisphere. However, it may be that it is not language, but analytical processing, which the left hemisphere controls.

Some research that supports the idea that it is the type of cognitive processing involved that determines how a language is lateralized is the work done with the Japanese orthography of Kana and Kanji (Bradshaw, 1980; Sasanuma, Itoh, Mori, & Kobayashi, 1977). Both Kana and Kanji are nonalphabetic symbols, with Kana the phonetic symbols for syllables, while Kanji are the nonphonetic, logographic symbols representing lexical morphemes. In this sense, these characters parallel the distinctions between English and ASL, as English consists of phonetic symbols while ASL is concerned with the morpheme structure. Early work with Japanese aphasic patients disclosed that the strategies used for decoding the two types of symbols were different, with Kanji utilizing a visual processing, in contrast to a phonological processing for Kana. Tachistoscopic experiments with Kana and Kanji words further supported these early findings by demonstrating a LHA for Kana and a RHA (nonsignificant) for Kanji. Sasanuma et al. (1977) suggest that while Kanji characters are fit candidates for a direct visual mapping or holistic type processing under some conditions, the characters are also associated with one or more phonological representations which may call up left hemisphere processing, thus presenting a more mixed picture of lateralization for Kanji. Determining the laterality of language in deaf individuals who communicate with ASL could shed further light on the role of types of processing in the determination of laterality.

Research with deaf individuals has begun only recently, and many of the studies are characterized by methodological difficulties. There have been major difficulties with the choice of tasks and strategies. Use of English words, letters, or manual alphabet do not insure linguistic mediation by the deaf (they may approach these as spatial tasks instead). Multiple choice or matching responses also enable the tasks to be approached in a spatial, holistic manner. One difficulty in the choice of tasks has been the reliance on tachistoscopic presentation of line drawings of sign. These signs, without the accompanying movements which is a central and salient aspect of ASL, cannot be considered as representative of the language of the deaf. Another major difficulty in research with deaf populations has been the failure to discriminate on the basis of early language training (oral vs. ASL) and age at which language is acquired. Early language training may be crucial in the development of laterality in the deaf, as some suggest that laterality begins to develop at an early age (Lenneberg, 1967) and different types of processing strategies may affect this laterality. Children raised in an oral environment are exposed to the English language with its accompanying syntax through oral presentation of words. Manual communication in an oral environment is often used to supplement the oral presentation of language, but continues to follow the English structure and syntax. In contrast, children raised with ASL as

their first language (as is most typically the case of deaf children with deaf parents) experience an entirely different language structure which may require a separate type of cognitive processing from ASL.

## Lateralization in the Deaf: Literature Review

McKeever, Hoemann, Florian, and Van Deventer (1976) were the first to investigate language laterality in the deaf. They presented four hemi-field visual-recognition tasks to congenitally deaf signers and hearing subjects who knew ASL. Three of the tasks used English letters and words, while one used drawings of ASL signs and manual letters. Hearing subjects showed LHA for two of the three English tasks and a RHA for manual alphabet. The deaf subjects also showed a LHA on one of the three English tasks (no difference on the others), but only a trend toward a RHA for the alphabet and signs. The authors concluded that auditory experience is a major determinant of cerebral lateralization. But this conclusion seems unwarranted. Their use of line drawings for the manual alphabet and static signs hardly seems comparable to ASL as the deaf use it and therefore does not appear to tap language. Second, they made no attempt to distinguish between the type of early language training the deaf experiences. Finally, the deaf and hearing

subjects used different response modes so that their results are not compatible.

Manning, Goble, Markman, and La Breche (1977), in another visual half-field experiment, presented English words, line drawings of signs, and shapes to deaf subjects and words and shapes to hearing subjects. They found a LHA for words for the hearing subjects and a trend in that direction for the deaf. No visual field advantage was shown by the deaf for signs or by either group for the shapes. In a second experiment (to increase the chances that the subjects deal with the stimuli linguistically), written words, photographs of signs, and words plus signs were presented bilaterally to the deaf, while just words were presented to the hearing. Subjects had to match the words or signs to pictures or objects on a board. Hearing subjects showed a LHA for words, while deaf subjects showed a trend toward LHA for words and RHA for signs. Manning et al. (1977), however, do not mention the signing skill of their deaf group, nor the group's early language training and whether or not they were native signers. A final problem mentioned by Poizner and Lane (1979) is that Manning et al. (1977) failed to use signs that were bilaterally symmetrical so that signs in the RVF would have been seen more clearly than signs in the LVF.

The only study to attempt to investigate differences in deaf populations based on early language training was

done by Phippard (1979). In this study, hearing subjects and two groups of prelingually deaf subjects (those with strict oral training and those with oral and manual training) were presented tachistoscopically English letter stimuli, line orientations, and human faces. In addition, the total communication group (those with early oral and manual training combined) viewed manual alphabet hand shapes. The hearing group showed the predicted LHA to English letters and the RHA to the lines and faces. The orally trained deaf showed a RHA to both English letters and lines, while the total communication group showed no visual field differences to any of the four tasks. Phippard's use of a matching response limits her findings somewhat in that this type of responding facilitates the use of a spatial matching (nonlinguistic) response. In addition, Phippard does not add to the knowledge on ASL processing as she used only the manual alphabet rather than signs and she does not say how fluent any of her total communication groups were with ASL or if they were native signers.

Neville and Bellugi (1978) had deaf native signers identify line drawings of ASL signs that were presented either unilaterally or bilaterally through a tachistoscope. In addition, both the deaf signers and hearing subjects unfamiliar with sign were presented a task requiring them to point to a dot location in a response matrix. Deaf subjects showed a significant LHA for both unilateral presented signs

and dots, but no laterality differences for bilaterally presented signs or dots. Hearing subjects showed only the expected RHA in localizing unilaterally presented dots. Neville and Bellugi conclude that the left hemisphere of deaf signers may function both for linguistic and certain nonlinguistic visual-spatial processing. Again, however, the use of line drawings of ASL restricts any inferences concerning language in the deaf. Also, their failure to find laterality effects for both hearing and deaf subjects when stimuli were presented bilaterally complicates the conclusions.

Lubert (reported in Poizner and Lane, 1979) asked subjects to match tachistoscopically presented stimuli to items on a board. Congenitally deaf and normal hearing subjects (sign language skills were not reported for either group) received English letters and photographs of ASL signs that could be identified without movement, photographs of manual alphabet handshapes, and a dot enumeration task. Both the deaf and hearing subjects showed a RHA to the ASL signs and no lateral differences to the other three tasks. Failure to find a LHA to English letters for the hearing subjects adds support to the hypothesis that matching tasks are not sufficiently complex to encourage verbal mediation, but instead result in spatial processing. Because of this, it is difficult to assess whether the deaf subject's RHA to the ASL signs is due to language processing or purely spatial matching.

Poizner and Lane (1979) attempted to avoid the lack of movement confound in assessing dominance for ASL by using photographs of signs that do not incorporate movement (signs of numbers). Other stimuli included photographs of non-ASL handshapes, arabic numbers, and random geometric shapes of low association value (non-linguistic spatial controls). Subjects were hearing adults unfamiliar with ASL and congenitally deaf (hereditary, unaccompanied by neurological involvement) adults with ASL as a first language. Both deaf and hearing subjects showed a RHA to the signs and non-ASL handshapes. In addition, hearing subjects showed a LHA to arabic numbers, while the deaf showed no reliable visual-field differences to the material. Neither the deaf nor the hearing subjects showed a reliable visual field advantage to the geometric forms. From an analysis of the response patterns, Poizner and Lane contended that the deaf subjects labeled the signs and processed the labels, while the hearing subjects relied exclusively on shape cues (as did the deaf and hearing for the non-ASL hands). While this contention appeared justified, their conclusion seemed less warranted. Instead of concluding that the right hemisphere in deaf individuals may be responsible both for spatial processing and for language (ASL), they inferred that the spatial processing required of the signs predominated over their language processing in determining the cerebral assymetry of the deaf. If the deaf subjects did approach the signed

numbers as lexical terms (as Poizner and Lane argue) and in a manner different from non-ASL hands and still obtained a RHA, then perhaps the right hemisphere is responsible for language in deaf native signers.

Scholes and Fischer (1979) investigated the relationship between linguistic competence in the deaf and laterality of language. Their subjects were grammatically skilled (based on their ability to comprehend passive sentences) deaf adolescents, grammatically unskilled deaf adolescents, and hearing college students. Onset of deafness for the two adolescent groups was pre-lingual. It was hypothesized that linguistic competence in the deaf would be associated with normal and near-normal laterality (LHA for analytic linguistic tasks). Subjects were shown a picture of a common object (e.g., lamp), followed by a brief unilateral presentation of a manually signed or orthographic letter, and they had to indicate as quickly as possible whether the letter was present in the spelling of the object's label. Hearing subjects showed a marked LHA for this task (orthographic letter), but no superiority was shown for either the linguistically skilled or unskilled deaf groups. Skilled subjects did show more of a trend toward RHA assymetries than did the unskilled subjects. The authors concluded that while hemispheric asymmetry did not develop normally in the deaf, the absence of this normal pattern did not preclude the development of the analytic skills necessary

to deal with the structure of language. It should be added that these investigators were investigating laterality of the English language per se and not the possible laterality of ASL. It is not clear how this may have affected laterality results.

Ross, Pergament and Anisfeld (1979) tested groups of congenitally deaf adults and hearing adults who had learned ASL as a native tongue at home. Three tasks were administered to the subjects tachistoscopically: a sign-word task (signs were videotaped), word-word task, and a letter task. In these tasks, the subjects had to respond as to whether the stimuli were the same or different. Hearing subjects showed the expected LHA for the letter task, while there was no difference for the deaf subjects. In the sign-word task, hearing subjects showed a LHA and deaf subjects a RHA. No significant effects relating to visual-field for the word-word task were found. These results present the strongest evidence to date for possible right hemisphere asymmetries for language (ASL) in the deaf and may be a function of the experimenter's ability to incorporate the movement of ASL through the use of videotapes. What Ross et al. (1979) did not show, however, is how a deaf-oral population with English as a first language would perform on this task, so that it is not clear if the differences are due to lack of auditory processing or differences in the processing strategies for English and ASL.

In summary, investigations concerning language laterality in deaf populations suggest that these individuals are lateralized differently and in fact may process sign language in the right hemisphere. However, methodological difficulties involving choice of stimuli (with the use of line drawings of the manual alphabet and static signs which ignore sign language's most salient feature--movement) and choice of response set (with matching responses being too simple to encourage verbal mediation, thus encouraging spatial matching) make it difficult to draw definite conclusions from the literature. In addition, researchers have added to the confusion with their sample populations which fail to make an important distinction between types of early language training of deaf individuals and by seldom giving information regarding their subjects' fluency with sign language.

## Current Research: Rationale and Objectives

The present study was interested in investigating cerebral laterality in deaf and hearing subjects through a tactile modality. While some researchers may argue that tactual representation is primarily a right hemisphere task (Witelson, 1974), recent research has suggested that it is not the nature of the stimuli per se (whether auditory, visual, tactual), but the processing strategy required that determines

the hemispheric specialization (Bever, 1975; Manning et al., 1977). The use of a tactile modality in assessing language laterality in the deaf is particularly useful since it avoids the complications inherent in attempts to present signs visually and allows deaf subjects to utilize whatever language strategy (English or ASL) is most efficient for them. In addition, a tachistoscopic study with stimuli similar to that used by Poizner and Lane (1979) was also employed. This dimension was used to serve as a reference point so that the tactile data from this study could be compared with the tachistoscopic research with deaf individuals.

Stimuli used in the tactile paradigm were line orientations and shapes. Line orientations, presented both unilaterally and bilaterally, in both the visual and tactual mode have consistently yielded a RHA (Benton, Levin, & Varney, 1973; Benton, Varney, & Hamsher, 1978; Oscar-Berman, Rehbein, Parfert, & Goodlass, 1978). This RHA holds for lines presented visually to the deaf population as well (Phippard, 1979). Research on the hemisphere advantage for shapes is more complex. Initially thought to be a right hemisphere task because of the spatial nature of the task (Dodds, 1978; Witelson, 1974), it now appears to depend on the degree to which the shapes encourage verbal mediation. In fact, as Kimura (1966) and others have shown, shapes must be exceedingly complex before verbal mediation is discouraged. Two measures used to encourage verbal mediation of the shapes

included bilateral presentation of the stimuli to increase the complexity of the task (if the task was too easy it would not be necessary for verbal mediation to occur) and the inclusion of a 10 second delay between presentation of stimuli and response to encourage verbal mediation through rehearsal (Oscar-Berman et al., 1978; Satz, Aschenbach, Pattishall & Fennell, 1965; Witelson, 1974). While these two strategies (bilateral presentation and delay) should have been sufficient to guarantee verbal mediation of the shapes, they were not expected to increase the complexity of the line task to require mediation (Harris, Bullard, Satz, Freund, Hutchinson, & Berg, 1980). Finally, the shapes used in the paradigm were ones considered to be more easily verbally mediated. These shapes were determined from a pilot study in which subjects were asked to label shapes after they felt them. Those shapes that lent themselves most readily to labeling were chosen for the study from a sample of shapes originally used by Witelson (1974). Witelson had used these shapes and found that subjects were more accurate in recognizing shapes felt by the left hand (possible RHA), but did not compare response hand (all responses were made with the left hand). Gardner, English, Flannery, Hartnett, McCormick and Wilhelmy (1976) used Witelson's shapes, controlling for response hand and also found an overall

advantage for shapes felt by the left hand, but this was complicated by a feeling hand x response hand interaction (which the authors discussed in terms of inter-hemispheric cross over and retrieval). Neither Witelson (1974) or Gardner et al. (1977) utilized a delay procedure as did this study. Cranney and Ashton (1980) employed Witelson's dichhaptic task with deaf and hearing populations and did not find a significant hemispheric advantage, but failed to control for pointing hand response, thereby possibly blurring laterality effects. La Breche, Manning, Goble and Markham (1977) also used Witelson's shapes with deaf and hearing children and found a significant right hand advantage for hearing children and a similar, though nonsignificant trend for the deaf children, suggesting that it is possible to call forth a left hemisphere strategy for these shapes (again, however, the authors did not control for response hand).

A second important aspect of the study was to assess the differential responses of three samples on these tasks. These three samples were hearing adolescents (Hearing), congenitally deaf adolescents with ASL as their native language (Sign), and congenitally deaf adolescents raised in a strict oral tradition with English as a first language (Oral). In order to avoid the controversy regarding the age of establishment of cerebral dominance (see Krashen, 1975, for a review of this literature), only adolescents 13 years of age or older were used. In any attempt to form separate and

distinct sample groups, issues of which variables to control for and match for are crucial. These variables became particularly salient in separating the deaf populations. In this study, the three groups were matched for age. Intellectual level as a factor was to be controlled statistically if it became a significant variable. Another issue of concern was the degree of hearing loss. Traditionally in research, the cut-off for deafness has been a loss of 85 db or greater in the better ear. While this was the accepted cut-off for this investigation, it was recognized that amount of residual hearing to a large degree depends on the type of loss (conductive vs. sensorineural) and the configuration of the loss (i.e., the amount of hearing at different frequencies, especially in the range of 250 hz to 4 k.).

## Specific Hypotheses

The purpose of this study was to investigate the effect of early language training on laterality in two different deaf populations. Hearing and congenitally deaf adolescents and young adults (with either English or ASL as a first language) were presented with bilateral dichaptic stimulation of two sets of stimuli, line orientations and shapes. In addition, they were exposed tachistoscopically to bilateral presentation of meaningful (ASL) and non-meaningful (non-ASL) line drawings of handshapes similar to those used by Poizner and Lane (1979). It was predicted that

(1) All three groups (Hearing, Oral and Sign subjects) would have higher accuracy scores and faster reaction times to lines presented to the left hand than to the ones presented to the right (demonstrating a RHA). If the shape stimuli tapped language through verbal mediation, then

(2) The Hearing and Oral group would demonstrate faster reaction times and obtain higher accuracy scores when the shapes were presented to the right hand (LHA), while the sign language groups would be more accurate and perform faster when the shapes were presented to the left hand. This was predicted because the Oral group, with its early training in English syntax, should more closely resemble normal hearing individuals, while it was predicted that deaf native signers, because of the visual-spatial nature of the signs and holistic, idiographic processing required, would rely more on right hemisphere processing. Finally, results of the tachistoscopic study were expected to parallel Poizner and Lane's (1979) results, with

(3) All three groups having higher accuracy scores and faster reaction times to both ASL and non-ASL handshape stimuli presented to the left visual half-field (RHA), although it was possible that the Oral group would demonstrate a LHA for the ASL hand shape by performing best with these stimuli presented to the right visual half-field.

# CHAPTER II
# METHODOLOGY

## Subjects

Group 1 (Hearing) consisted of 20 hearing adolescents and young adults selected from Bradford High School in Starke, Florida. Group 2 (Oral) comprised 18 congenitally deaf adolescents and young adults raised in an oral environment with English as their first language. Group 3 (Sign) comprised 20 congenitally deaf adolescents and young adults with ASL as their first language. The deaf subjects were chosen from the Florida School for the Deaf and Blind (FSDB) in St. Augustine, Florida. School records, parental reports and teachers' reports were used to establish early language training with the deaf students. To be included in a group, deaf subjects had to be exposed to the particular language training through at least the first six years of life (with many experiencing the same language environment for the first 12 years). By 12 years of age, many of the children had transferred to FSDB and at the time of the study were all fluent in ASL and used this mode when talking with peers, regardless of early language training.

All subjects were white and were right handed as measured by at least a 70% right hand preference (including

writing), on the 10 unimanual tasks of the Harris Test of Lateral Dominance (Harris, 1958). Each group consisted of an equal number of males and females between the ages of 13 and 21 years.

Subjects in the three groups were matched for age. Mean ages for the three groups were as follows: Hearing subjects --16 years, 7 months; Oral subjects--16 years, 6 months; and ASL subjects--16 years, 7 months. Only those adolescents and young adults free from any neurological impairment or handicap (other than deafness) were included. Amount of hearing loss for the two deaf groups was set at 85 db or greater average loss in the better ear ($\bar{x}$ loss for Oral subjects--91 db; $\bar{x}$ loss for ASL subjects--93 db). Intellectual functioning (as measured by the Performance Scales of the Wechsler Intelligence Scale for children--Revised or the Wechsler Adult Intelligence Scale) was assessed. Mean IQ scores for the three groups were as follows: Hearing subjects--116; Oral subjects--111; and ASL subjects--111. Subject characteristics by group and sex are summarized in Table 1.

## Stimuli

Four sets of stimuli were presented, two in the tactile mode and two in the visual mode. The tactile stimuli were shapes and lines. The visual stimuli were line drawings of ASL handshapes and nonsense handshapes.

Table 1. Subject Characteristics

| | Hearing Males | Hearing Females | Oral Males | Oral Females | Sign Males | Sign Females |
|---|---|---|---|---|---|---|
| $\bar{x}$ Age | 16.4 | 16.8 | 16.3 | 16.7 | 16.3 | 17.0 |
| (range) | (14.2-18.75) | (14.7-20.4) | (13.0-19.4) | (14.4-19.3) | (13.0-20.1) | (13.5-19.3) |
| (S.D.) | 1.6 | 1.6 | 2.1 | 1.3 | 2.25 | 1.7 |
| $\bar{x}$ IQ | 113 | 114 | 113 | 109 | 109 | 113 |
| (range) | (95-130) | (102-129) | (81-126) | (192-120) | (92-131) | (91-125) |
| (S.D.) | (8.59) | (9.68) | (11.74) | (7.14) | (12.20) | (10.97) |
| $\bar{x}$ Hearing Loss (ab) | | | 89.25 | 93.22 | 92.66 | 93.7 |
| (range) | | | (85-97) | (85-105) | (85-100) | (85-110) |
| (S.D.) | | | (5.09) | (6.20) | (5.43) | (7.36) |

Tactile

Shapes. The stimuli were 10 different wooden shapes, each having four to eight sides and were 1 1/2 x 1 1/2 x 3/16 inches in size. These shapes were selected from Witelson's shapes (1974) following a pilot study by the author which suggested that these shapes were more readily verbally mediated. (Subjects responded with a verbal label more rapidly to these shapes.) No one shape was a spatial reversal of another. The 10 shapes were arranged in five pairs, such that the general outline and the numbers of angles and curved sides were similar within pairs of stimuli. Each pair of stimuli was glued with a 4-inch horizontal separation between them, to the central portion of an 8 x 11 inch board. A visual display of six shapes drawn to size on a card, consisting of the two correct shapes, two other test stimuli, and two distractors was used in the response portion of the test. The six stimuli were arranged in a predetermined but random circular arrangement in order to discourage left-right scanning. The display stimuli were counterbalanced for display position and frequency of occurrence. Ten different recognition displays were used.

Lines. The stimuli were 10 different line orientations, with angles of .50, 30, 45, 60, 75, 105, 120, 135, 150 and 165 degrees from the horizontal axis. These line orientations were formed by gluing wooden sticks 2 inches long on to the central portion of an 8 x 11 inch board with a 4-inch

horizontal separation between them. The following angle degrees were paired and presented bilaterally: .50 and 30; 45 and 60; 75 and 105; 120 and 135; 150 and 165. Visual displays of six line orientations were drawn onto cards, consisting of two correct stimuli and four other test stimuli and used for recognition of the correct response. The lines were arranged in the same manner as the visual display of shapes and 10 different line recognition displays were used.

## Visual

ASL handshapes. These stimuli consisted of four ASL signs that require no movement for recognition (although, in common use, they often take on movement with added meaning). These signs were the signs for the numbers six, seven, eight and nine. The stimuli were 3 cm in width and 9.5 cm in height and were presented tachistoscopically 3° to the left or right of center fixation point to assure processing by the specific visual half-field. Each ASL number was paired with every other ASL number (six pairs) and then interchanged as to left-right arrangement, for a total of 12 trials. Figure 1 presents the ASL handshape stimuli employed in the study.

Non-ASL hands. These stimuli consisted of four line drawings of hand configurations that never occur in ASL. The stimuli were 3 cm in width and 9.5 cm in height and were presented 3° to the left or right of center fixation point

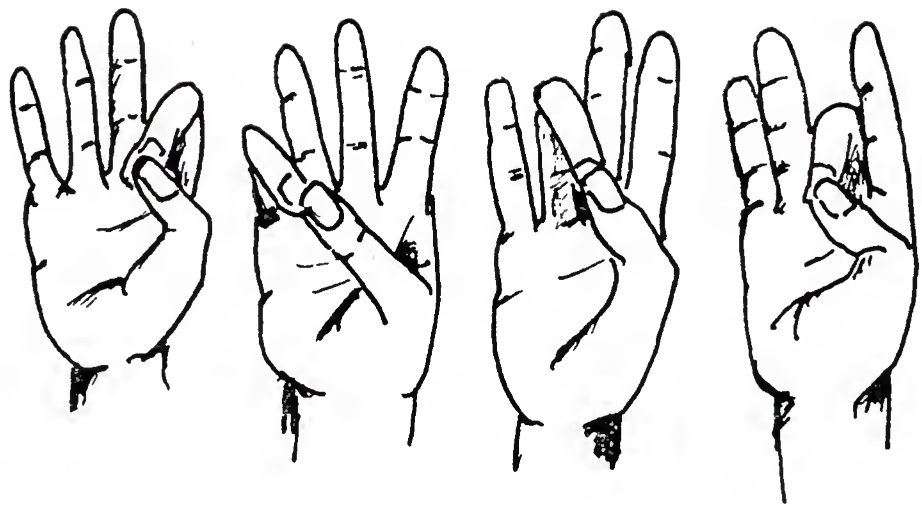


Figure 1

ASL Handshapes

to confine the processing to a specific visual half-field. Each stimulus was paired with every other stimulus and then interchanged as to left-right arrangement, for a total of 12 trials. Figure 2 presents the non-ASL stimuli employed in the study.

## Apparatus and Procedure

Initially, a baseline for speed of response for right and left hands was established for each individual. This was done by having the subjects respond to the presentation of a visual display of dots by touching the center dot on the display. Response hand was signaled (left or right) prior to the stimulus display by an experimenter touching the corresponding shoulder of the response hand. If the subject's right shoulder was touched, the subject responded with his/her right hand. If the subject's left shoulder was touched, he/she responded with his/her left hand. Left or right response was randomized between hands over 10 reaction time trials.

Each subject was given six pretest trials with feedback as to the correct answers (using nontest stimuli) for both the tactile and visual paradigms. The purpose of the pretest trials was to familarize the subjects with the general nature and procedures of the tests.

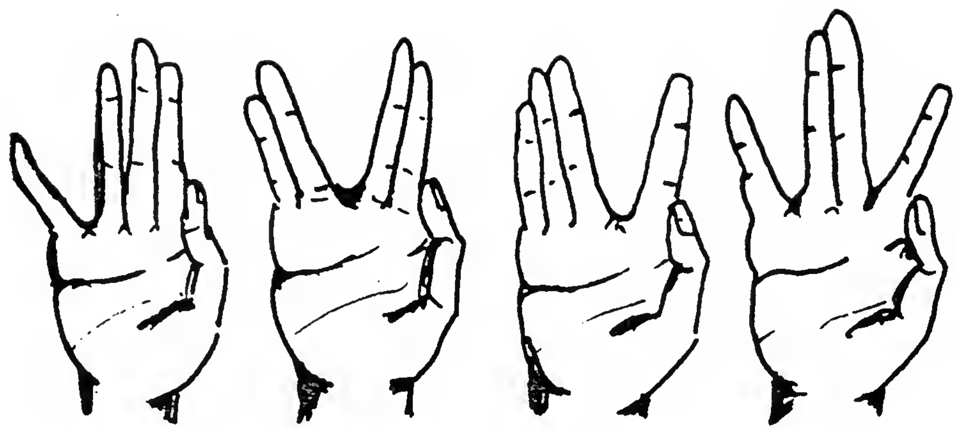


Figure 2

Non-ASL Handshapes

## Tactile Presentation

The tactile tests consisted of 20 trials, each involving simultaneous presentation of a pair of different stimuli. Each of the five pairs was presented four times, with the two stimuli interchanged as to the left-right arrangement so that each shape was presented twice to the subject's left hand and twice to his/her right hand. The stimuli were presented to the subject with a partition positioned between the subject and the experimenter, thus preventing subjects from seeing the stimuli. The partition had an opening which allowed for placement of the subject's hands so that he/she did not have to search for the stimuli and so that each hand only touched the left or right stimulus. At the start of any trial, the subject placed his/her hands inside the two openings. The subject's hands were positioned so that the marks drawn on his/her wrists were in line with those on the base of the entrance of the partition. A board with an attached pair of stimuli was then slid into place under the subject's hands. When the subject lowered his/her hands, his/her fingers made contact with the stimuli. Each pair of stimuli was presented for 10 seconds. Following this, a 10 second delay occurred before the presentation of the visual display. With this display, the subject's response was then made by pointing to the correct stimuli. The response hand was indicated just prior to the presentation of the visual

display by an experimenter touching the corresponding shoulder of the response hand as in the reaction time trials. Reaction time was defined as the time interval between visual presentation of the response card and the manual response. No time limit nor feedback for a response was given on the test trials, but reaction time was measured. Subjects were asked to select two stimuli on each trial, even if they had to guess which stimuli they felt. Half of the subjects in each group (controlled for sex) received the shape stimuli first and the other half received the line orientation first.

## Visual Presentation

A three field tachistoscope (Gerbrands, Model T-3B2) was employed to present the visual stimuli with luminances of each field set equal. Subjects viewed the two sets of stimuli, with the ASL and non-ASL hand shapes intermixed randomly, making a total of 24 trials. Three additional trials were inserted at separate points during the stimuli presentation to insure center fixation. These trials comprised small, three letter words flashed to the center of the visual field and were read by the subjects. The subject saw the following sequence of events. A fixation dot appeared for four seconds at the beginning of each trial. Immediately following the dot, the handshape pair was presented bilaterally for 500 msec. There then followed a 10 second delay before the presentation of the visual display response

sets. These visual displays were presented directly above the tachistoscope viewer so that the subject had only to sit back slightly to view the display. During the 10 second delay, while the subjects tried to remember the handshapes viewed, the experimenter signaled which hand (left or right) should be used in making the response. This was done in the same manner as in the reaction time trials. Each subject was then required to select from two stimuli that were presented from a display of six handshapes. Reaction time for each trial was measured from the time the experimenter presented the response display until the subject made his/her first choice.

## Statistical Analysis

Dependent measures for the four experiments were mean percentage correct and mean reaction time to response. A 3x2x2x2x2 (group x sex x feeling hand x response hand x time) repeated measures analysis of variance was performed on the tactile experiments (shapes and lines) with group and sex the between groups factors and feeling hand, response hand and time the within group factors. Group refers to the three subject samples, Hearing, Oral, and Sign and sex to male and female. Feeling hand refers to which hand (left or right) felt the stimulus, and response hand to which hand (left or right) made the response. Time is concerned with

the grouping of trials with time 1 referring to trials 1-10 and time 2 to trials 11-20 (which are a repetition of the first ten trials). For the visual experiments (ASL handshapes and non-ASL handshapes), a 3x2x2x2x2 (group x sex x visual half-field x response hand) was employed, with group and sex the between groups factors and visual half-field (left or right) and response hand the within group factors.

Initial analyses of variance were performed using the P2V-Analysis of Variance and Covariance Including Repeated Measures statistical package of the Biomedical Computer Programs-P Series Statistical Software (Dixon, 1981). When significant interactions made further analysis necessary, the General Linear Models Program from the Statistical Analysis System User's Guide (Hewlig & Council, 1979) was used to provide appropriate analyses of variance. The statistical analyses were performed with the assistance of the Biostatistic Department of the University of Florida.

# CHAPTER III
# RESULTS

Separate analyses were performed for the four experiments: Shapes, Lines, ASL handshapes and non-ASL handshapes. Dependent variables for all experiments were mean percentage of correct responses and mean reaction time to response. Initially, individual reaction times for each subject were converted for differences in rapidity of right versus left response hands by subtracting the average time to response scores obtained for each hand at the beginning of the testing session. The tactile experiments (Shapes and Lines) were analyzed in a 3(group) x 2(sex) x 2(feeling hand) x 2(response hand) x 2(time) repeated measures design with group and sex the between groups factors and feeling hand, response hand and time the within group factors. The visual experiments (ASL handshapes and non-ASL handshapes) were analyzed in a 3(group) x 2(sex) x 2(visual half-field) x 2 (response hand) repeated measures design group and sex the between groups factors and visual half-field and response hand the within group factors. Preliminary analysis showed no difference for sex, group, or sex x group for age or IQ; therefore these variables were not considered in later analyses. (See Tables 2 and 3 in Appendix for summary tables of analyses of variance.)

## Experiment 1: Shapes

### Analysis of Percentage Correct Responses

Initially, the repeated measures analysis of variance was performed on mean percentage correct for the shape stimuli. Main effects were found for sex ($F(1,51)=6.11$ $p<.05$), time ($F(1,51)=13.65$ $p<.001$), and response hand ($F(1,51)=8.09$ $p<.01$). No main effects were found for group or feeling hand and there was no group x feeling hand interaction. The main effects that were found, however, can best be interpreted in the light of significant interactions between time, feeling hand, and sex ($F(1,51)=6.72$ $p<.05$) and between time and response hand ($F(1,51)=24.80$ $p<.001$). Separate analyses for time 1 and time 2 demonstrated a significant effect for sex (males females) at time 1 (Reduced Model: $F(1,18)=9.12$ $p<.01$) and a sex x feeling hand interaction at time 2 (Reduced Model: $F(1,18)=7.77$ $p<.05$). In addition, an effect for response hand (with the left hand being more accurate than the right) was evident at time 1 (Reduced Model: $F(1,18)=44.68$ $p<.001$), but with their being no difference by time 2. (See Table 4 in Appendix for analysis of variance summary.)

Specifically, at time 1 for the Shape stimuli, males were more accurate than females regardless of feeling hand. By time 2, females had improved sufficiently on shapes felt with their left hand so that there was no longer a difference

between males and females. Females, however, remained significantly less accurate on Shapes felt by their right hand. These results are presented pictorially in Figure 3. Finally, subjects (regardless of sex) were more accurate at time 1 when their response was made with the left hand. By time 2, response with the right hand had improved significantly, so that there was no difference in accuracy between response hands (Figure 4).

## Analysis of Reaction Time Data

The repeated measures analysis of variance for mean reaction time to response for shapes yielded a main effect for group ($F(2,51)=8.71$ $p<.001$) and for time ($F(1,51)=9.86$ $p<.01$), as well as a time x group ($F(2,51)=3.56$ $p<.05$) and a time x response hand ($F(1,51)=4.46$ $p<.05$) interaction. Analyzing these interactions separately for time 1 and time 2, the Hearing group was significantly faster than the two deaf groups at both time 1 and time 2 (Reduced Models: $F(2,25)=9.08$ $p<.001$; $F(2,26)=6.20$ $p<.01$) and there was no significant difference in speed of response between the deaf groups at either time. However, the sign group did respond significantly faster by time 2 as compared with their responses at time 1 (Duncan's Multiple Range/corrected for unequal n's $p<.05$). (Figure 5 presents these results.) Paralleling the improved accuracy for the right pointing hand found with Shapes, pointing with the right hand as shown in

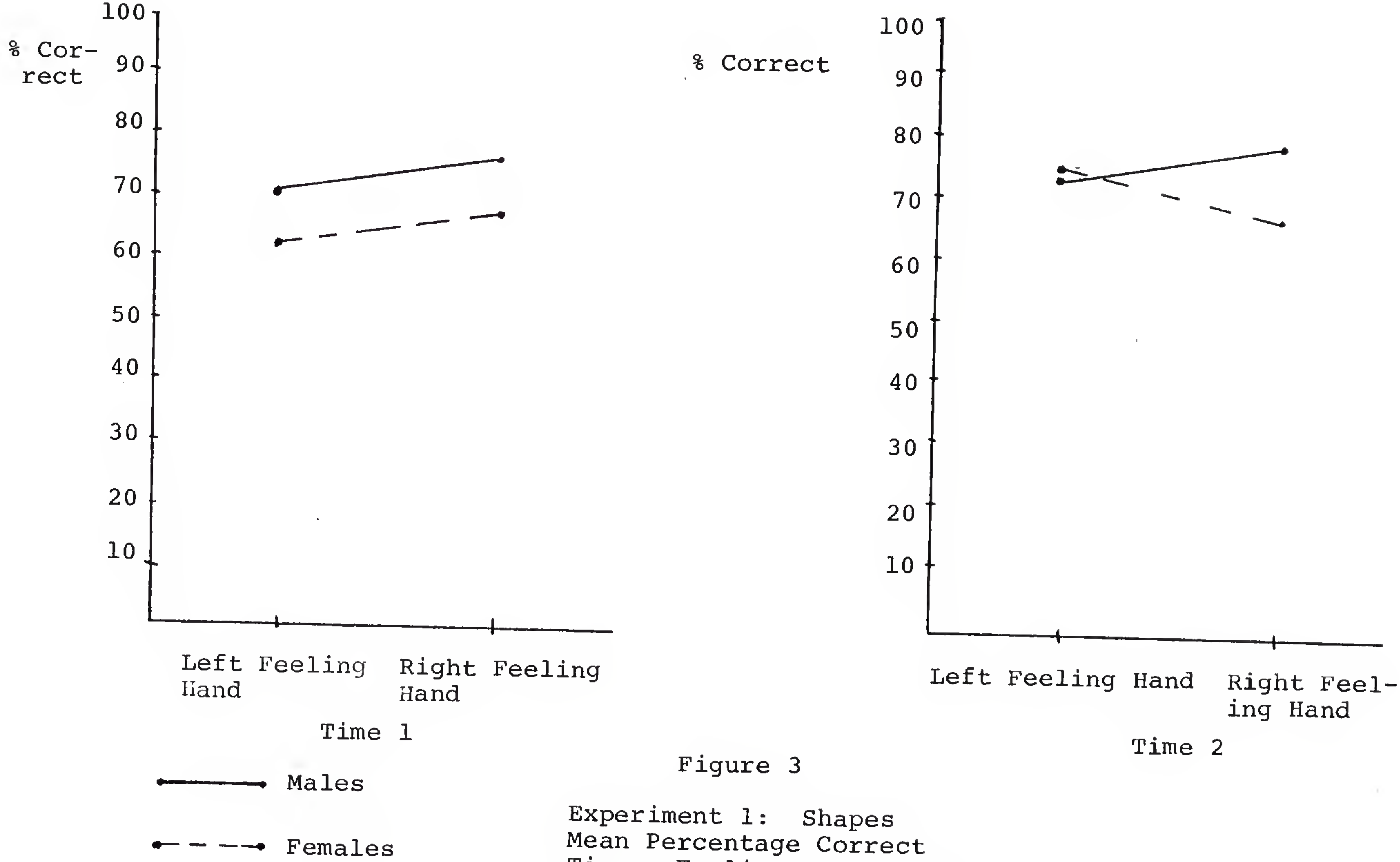



Figure 3

Experiment 1: Shapes
Mean Percentage Correct
Time x Feeling Hand x Sex

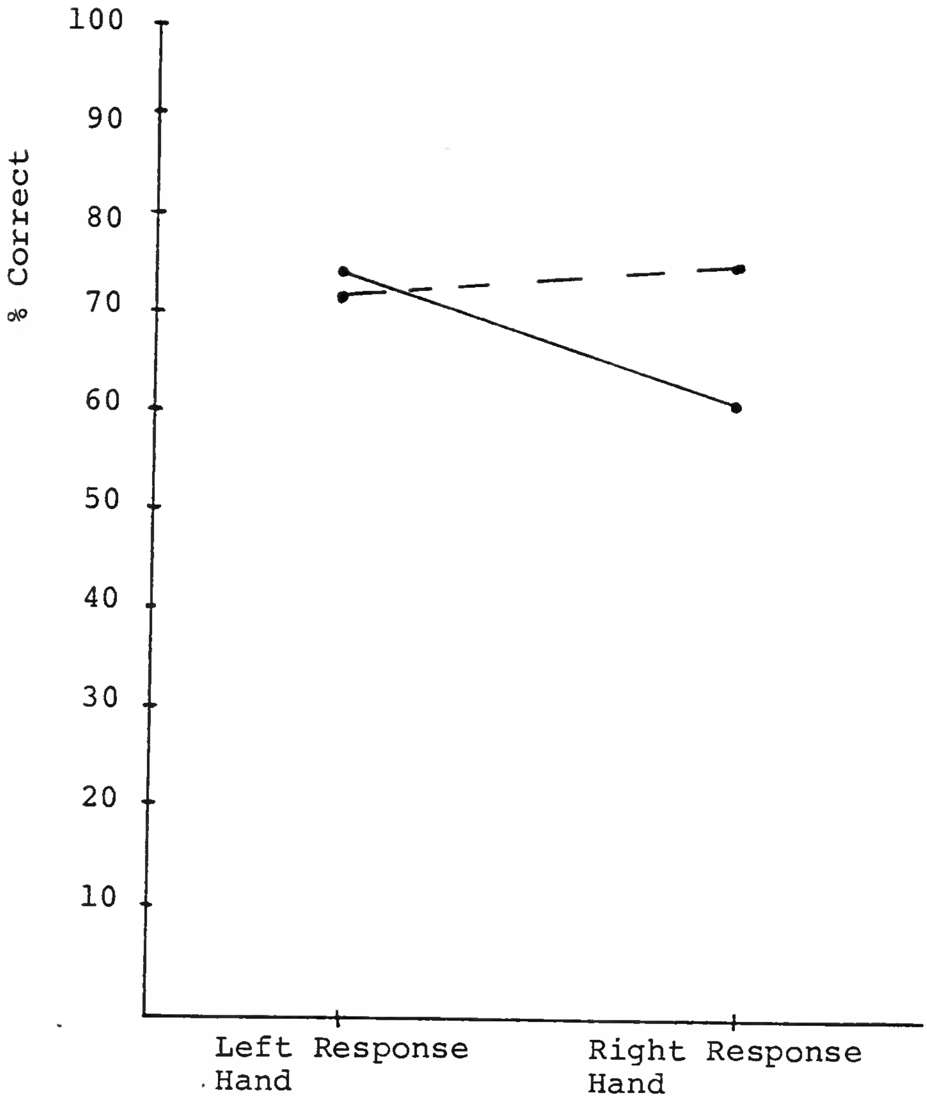
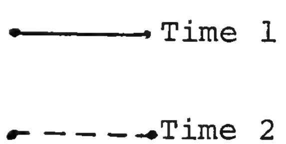



Figure 4

Experiment 1: Shapes
Mean Percentage Correct
Time x Response Hand



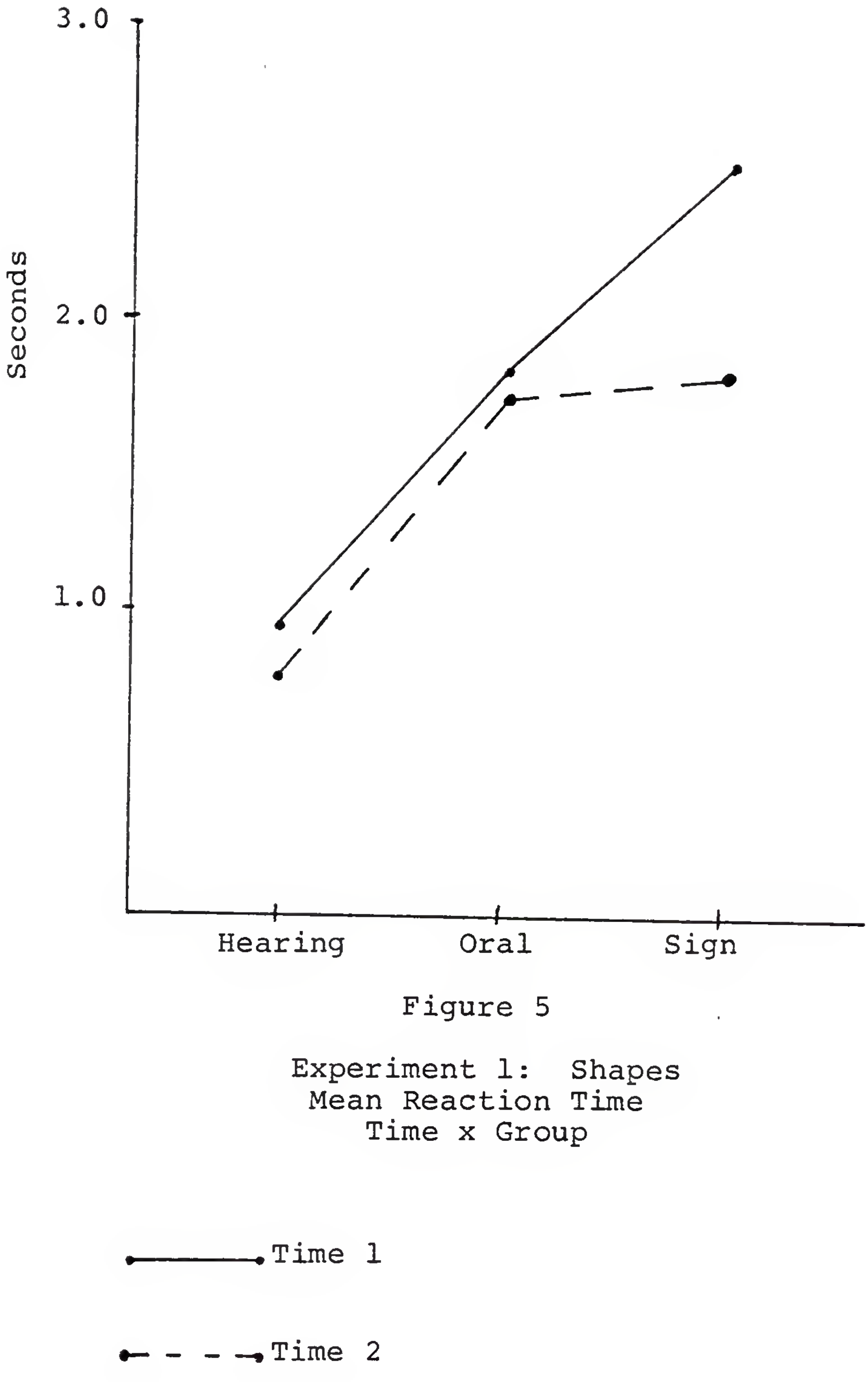



Figure 5

Experiment 1: Shapes
Mean Reaction Time
Time x Group

Figure 6 became faster with time and was significantly faster than responses with the left hand at time 2 ($F(1,26=12.92$ $p<.001$). Table 5 in the Appendix presents the summary of analysis of variance.

## Experiment 2: Line Orientations

### Analysis of Percentage Correct Responses

Repeated measures analysis of variance for mean percentage correct yielded a main effect for feeling hand ($F$ $(1,51=17.81$ $p<.001$). No other main effects were observed. While the main effect for feeling hand was in the predicted direction (with lines felt by the left hand being more accurately perceived than those felt by the right), this effect was complicated by the following interactions: response hand x time ($F(1,51)=61.83$ $p<.001$); response hand x sex ($F$ $(1,51)=4.23$ $p<.05$); feeling hand x time x sex ($F(1,51)=11.19$ $p<.01$); and feeling hand x time x response hand ($F(1,51)=$ $22.96$ $p<.001$). Table 6 in the Appendix contains a summary of this analysis of variance.

More specifically, accuracy for line orientations varied with hand of input, hand of response output, sex, and time. Generally, across time, males were equally accurate in responding with both hands and were as accurate as females with their right hand. Females, however, were significantly poorer when a left hand response was called for

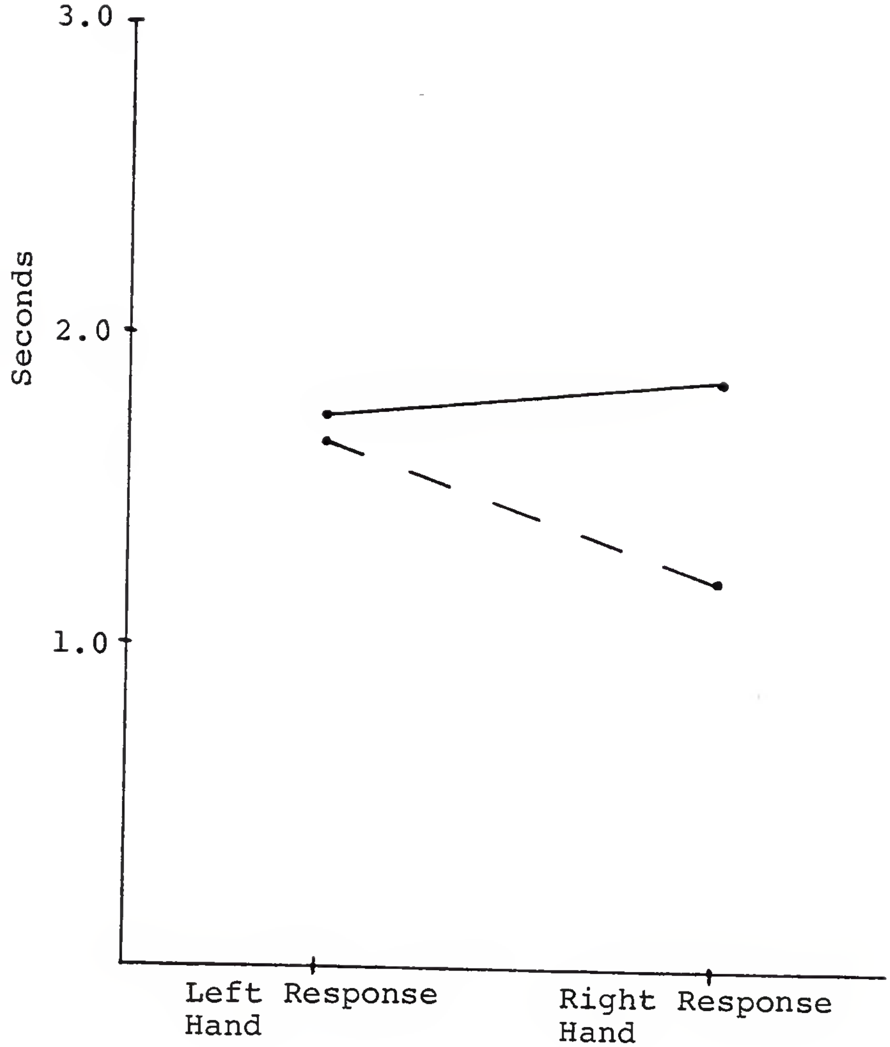



Figure 6

Experiment 1: Shapes
Mean Reaction Time
Time x Response Hand

Time 1

Time 2

(Duncan's Multiple Range/corrected for unequal n's $p<.05$ (DMR)). (Figure 7 depicts this interaction.) Looking further at how males and females performed, according to which hand felt the stimuli, it appears that at time 1, males were significantly more accurate in feeling lines with the left than the right hand. No differences between the hands were found for the female subjects nor did performance by either hand for the female subjects differ from the right hand scores of the male subjects (DMR $p<.05$). By time 2, however, males had improved their performance when lines were presented to the right hand and females had improved when lines were presented to the left hand such that there was no differences between males feeling with left hand, males feeling with right hand and females feeling with left hand. Females, however, remained significantly less accurate (DMR $p<.05$) when lines were presented to their right hand. This interaction can be seen most clearly by viewing Figure 8.

Finally, analyzing feeling hand x responding hand separately for time, a feeling x responding hand effect is evident (Reduced Model: $F(1,18)=18.36$ $p<.001$). At time 1, feeling left-responding left, feeling left-responding right, and feeling right-responding left are equally as accurate and are more accurate than feeling right-responding right. By time 2, accuracy remains virtually the same for either responding hand for feeling right (with some improvement in feel left-respond right), but for feel right, the response hand

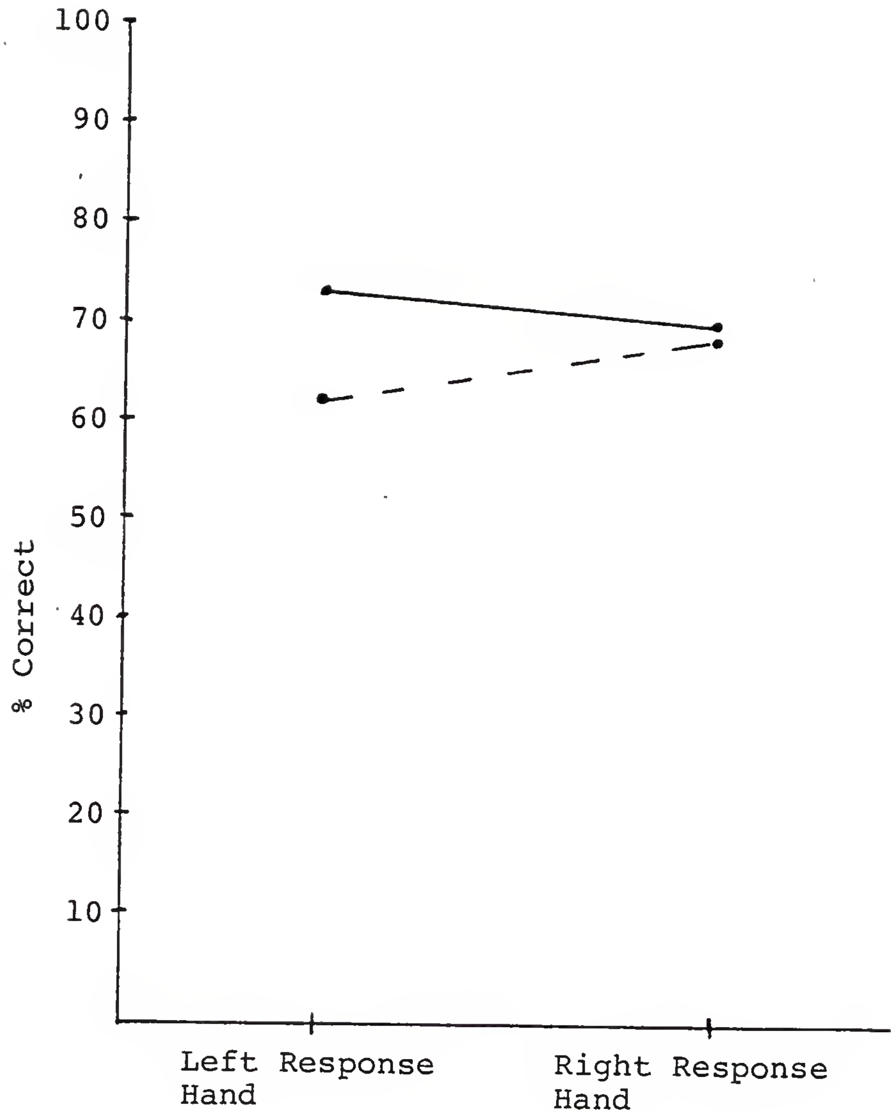



Figure 7

Experiment 2: Line Orientations
Mean Percentage Correct
Sex x Response Hand

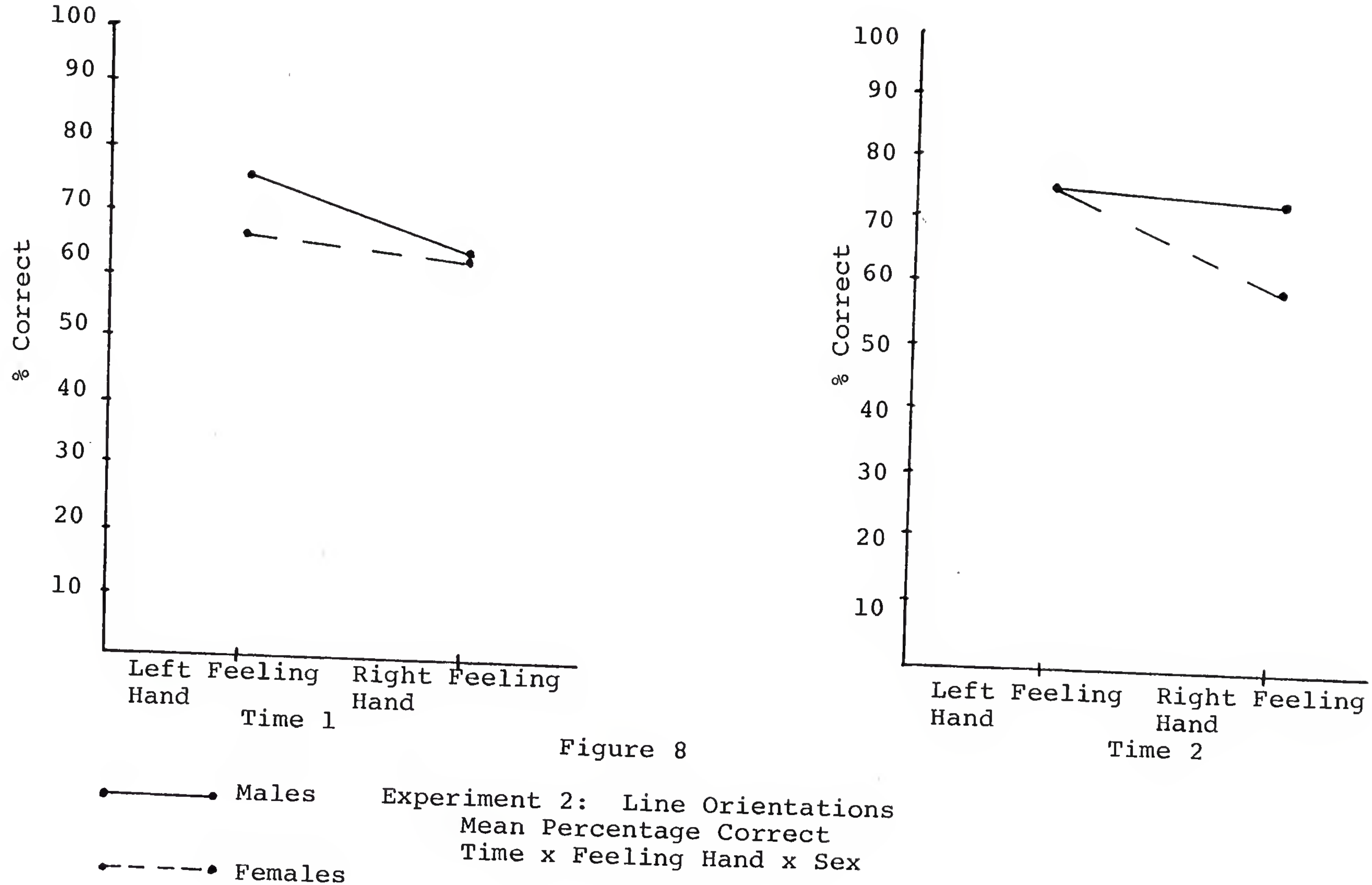



Figure 8

Experiment 2: Line Orientations
Mean Percentage Correct
Time x Feeling Hand x Sex

accuracy scores have reversed so that feel right-respond right is as accurate as either feel left score and is significantly better than feel right-respond left (DMR $p<.05$). Figure 9 presents this reversal in accuracy scores.

## Analysis of Reaction Time Data

Repeated measures analysis of variance for mean reaction time to line orientations yields a main effect for time, with all subjects performing faster at time 2 than time 1 ($F(1,51)=4.24$ $p<.01$) (Figure 10) and a main effect for group ($F(2,51)=84.76$ $p<.01$). Use of Duncan's Multiple Range (corrected for unequal n's) indicates that the Hearing group is significantly faster than both deaf groups ($p<.05$) and that there is no difference between the Oral group and Sign group in terms of speed of response (see Figure 11). Summary of the analysis of variance is included in Table 7 of the Appendix.

# Experiment 3: ASL Handshapes

## Analysis of Percentage Correct Responses

The repeated measures analysis of variance for the ASL handshapes demonstrated a main effect for group ($F(2,51)=49.03$ $p<.001$) with the Sign group perceiving the handshapes more accurately than did the Oral group and with both groups being more accurate than the Hearing subjects (DMR $p<.05$).

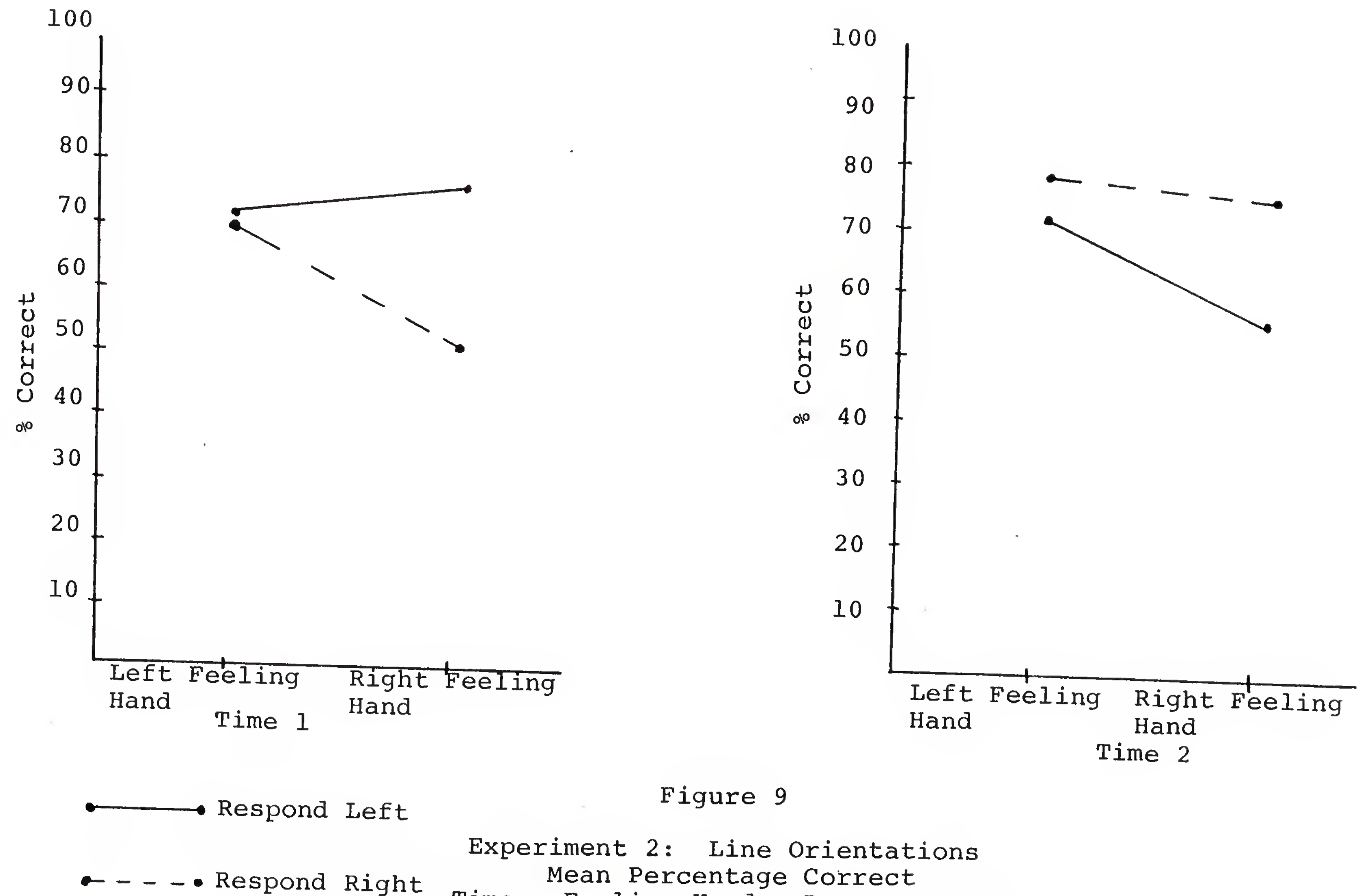



Figure 9

Experiment 2: Line Orientations
Mean Percentage Correct
Time x Feeling Hand x Response Hand

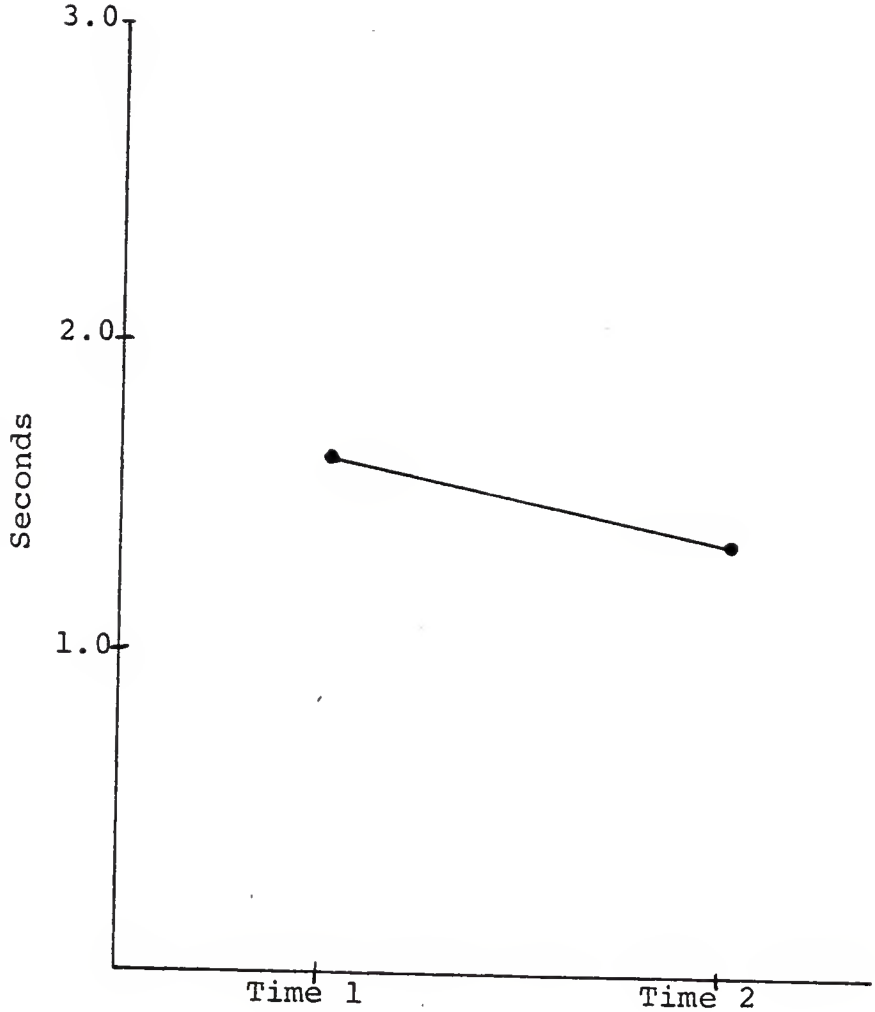



Figure 10

Experiment 2: Line Orientations
Mean Response Time

Time

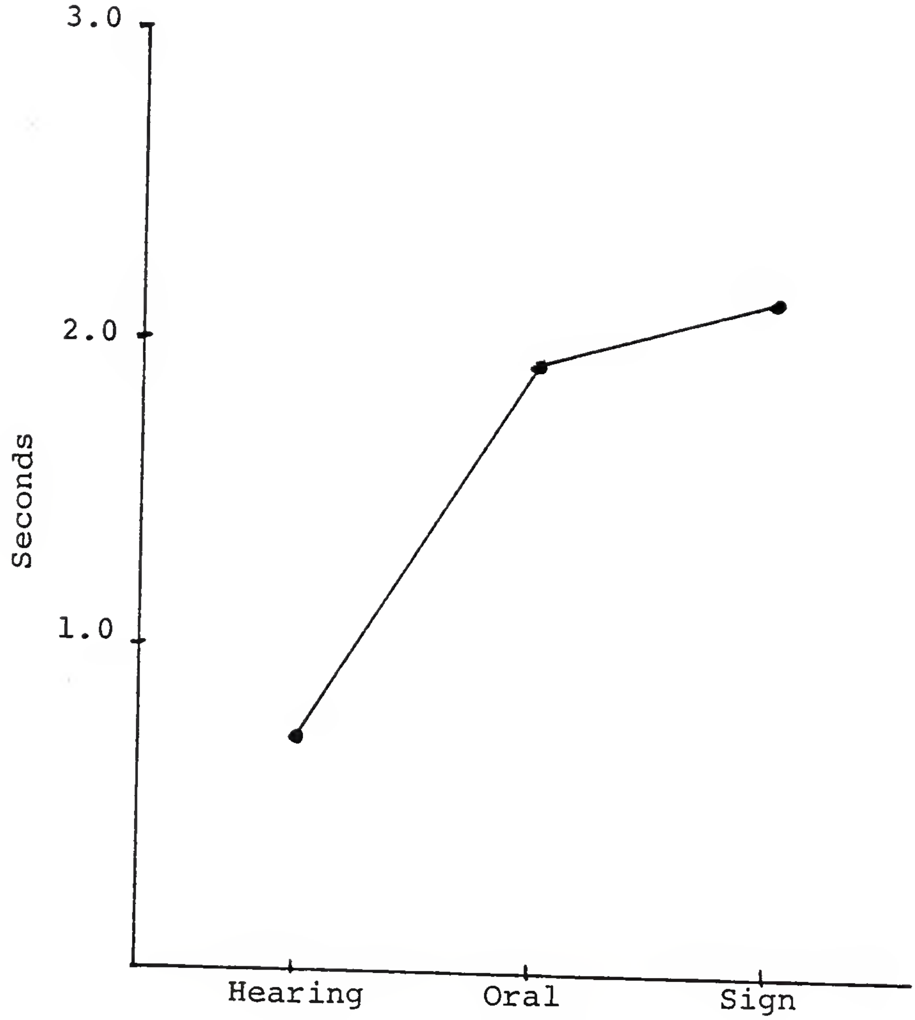



Figure 11

Experiment 2: Line Orientations
Mean Reaction Time

Group

This finding in effect validates the composition of the three sample populations by demonstrating that even though both groups were fluent in ASL, the Sign group's early training in ASL resulted in significantly higher accuracy scores for the ASL handshapes than the Oral group. Figure 12 demonstrates this effect for group. No main effect was found for visual half-field and there was no visual half-field x group interaction. However, a significant three-way interaction was found for visual half-field x response hand x sex ($F(1,51)=5.88$ $p<.05$). Table 8 in the Appendix contains the summary of the analysis of variance.

Separate analyses for sex reveal a significant interaction between visual half-field and response hand for male subjects ($F(1,36)=5.35$ $p<.05$), while this effect is not evident for the females. Specifically for males, subjects were more accurate when input and output occurred within the same hemisphere (i.e., left visual half-field-left response hand; right visual half-field-right response hand) than when it was necessary for cross-hemispheric processing to occur (left visual half-field-right response hand; right visual half-field-left response hand). This effect is seen in Figure 13.

## Analysis of Reaction Time Data

Analysis of variance for mean reaction time to ASL handshapes demonstrated no significant main effects for

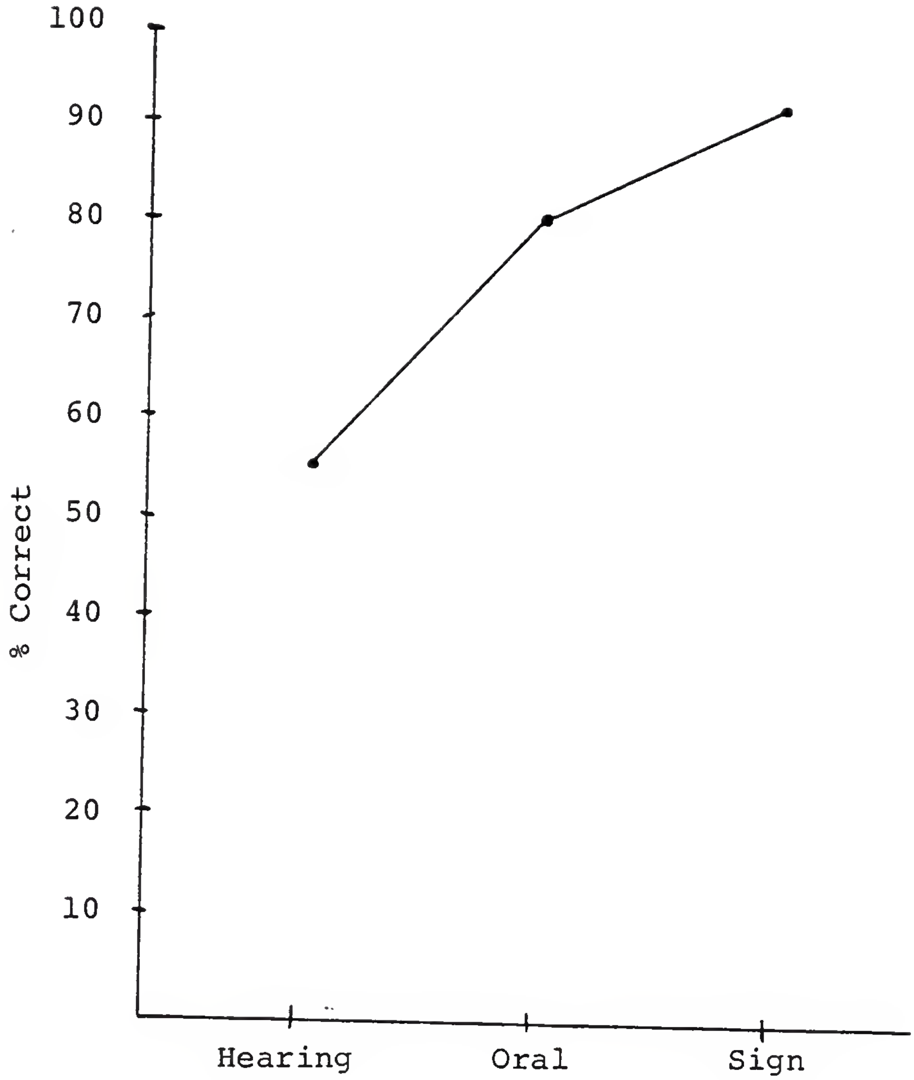



Figure 12

Experiment 3: ASL Handshapes
Mean Percentage Correct

Group

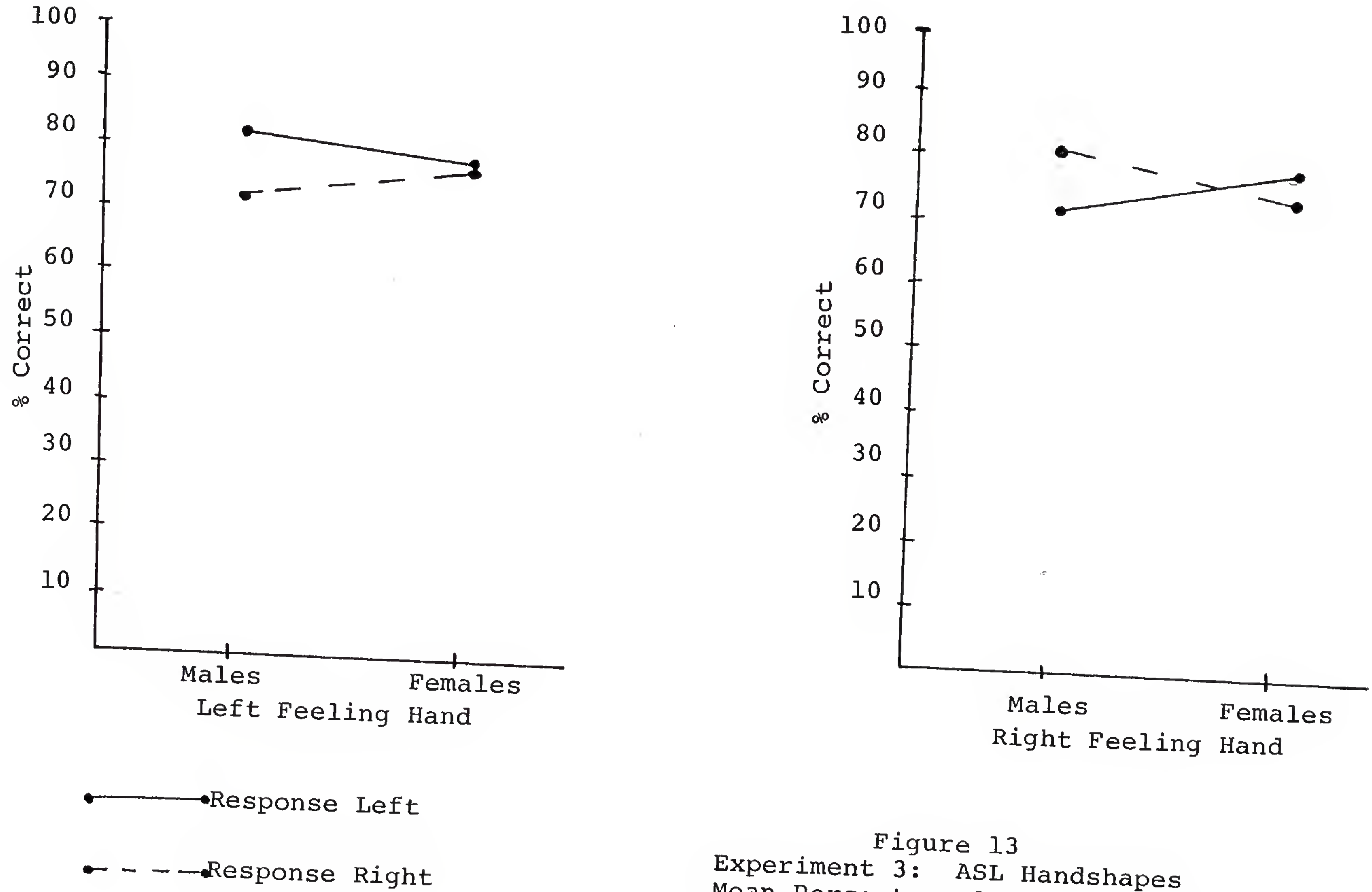



Figure 13
Experiment 3: ASL Handshapes
Mean Percentage Correct
Feeling Hand x Response Hand x Sex

group, sex, visual half-field or response hand and no significant interactions. Table 9 in the Appendix contains the analysis of variance summary.

## Experiment 4: Non-ASL Handshapes

### Analysis of Percentage Correct Responses

The analysis of variance with repeated measures for the non-ASL handshapes revealed a main effect for response hand, with subject's being more accurate when they responded with their left hand ($F(1,51)=20.24$ $p<.001$). Again, however, this main effect was embedded in a visual half-field x response hand x sex interaction ($F(1,51)=8.61$ $p<.01$).

Separating this interaction by left and right visual half-fields and performing a reduced model analysis of variiance yield an effect for sex (males>females)($F(1,18)=$ $p<.05$), response hand (left>right)($F(1,18)=14.09$ $p<.01$), and a sex x response hand interaction ($F(1,18)=7.35$ $p<.05$). No effects were noted for sex or response hand when handshapes were viewed in the right visual half-field. Analyzing the sex x response hand interaction for left feeling hand further, it appears that in terms of mean percentage correct for meaningless handshapes, there was no difference for sex or response hand when handshapes were viewed in the right visual half-field. However, when these non-ASL handshapes were viewed in the left visual half-field, females

did significantly worse than males when they were required to respond with their right hand. Females viewing these handshapes in the left visual half-field and responding with the left hand were equally as accurate as the males (regardless of which hand the males responded with). Figure 14 presents this interaction. A summary of the analysis of variance is contained in Table 10 in the Appendix.

### Analysis of Reaction Time Data

Repeated measures analysis of variance for mean reaction time to the non-ASL handshapes yielded no significant effects for group, sex, visual half-field or response hand and no significant interactions. Table 11 in the Appendix contains a summary of this analysis of variance.

## Individual's Lateral Directional Preference

Because no group effects were observed for hemispheric laterality across the four tasks, individual subject's directional preference for laterality was observed post hoc to determine if group averaging had obscured clear individual differences for laterality. These directional preferences were determined by assigning the number one to the condition containing the highest percentage correct for each of the four tasks. These conditions were input left field-output left hand (LL), input right field-output right hand (RR), and an averaged percentage combination of the two crossed

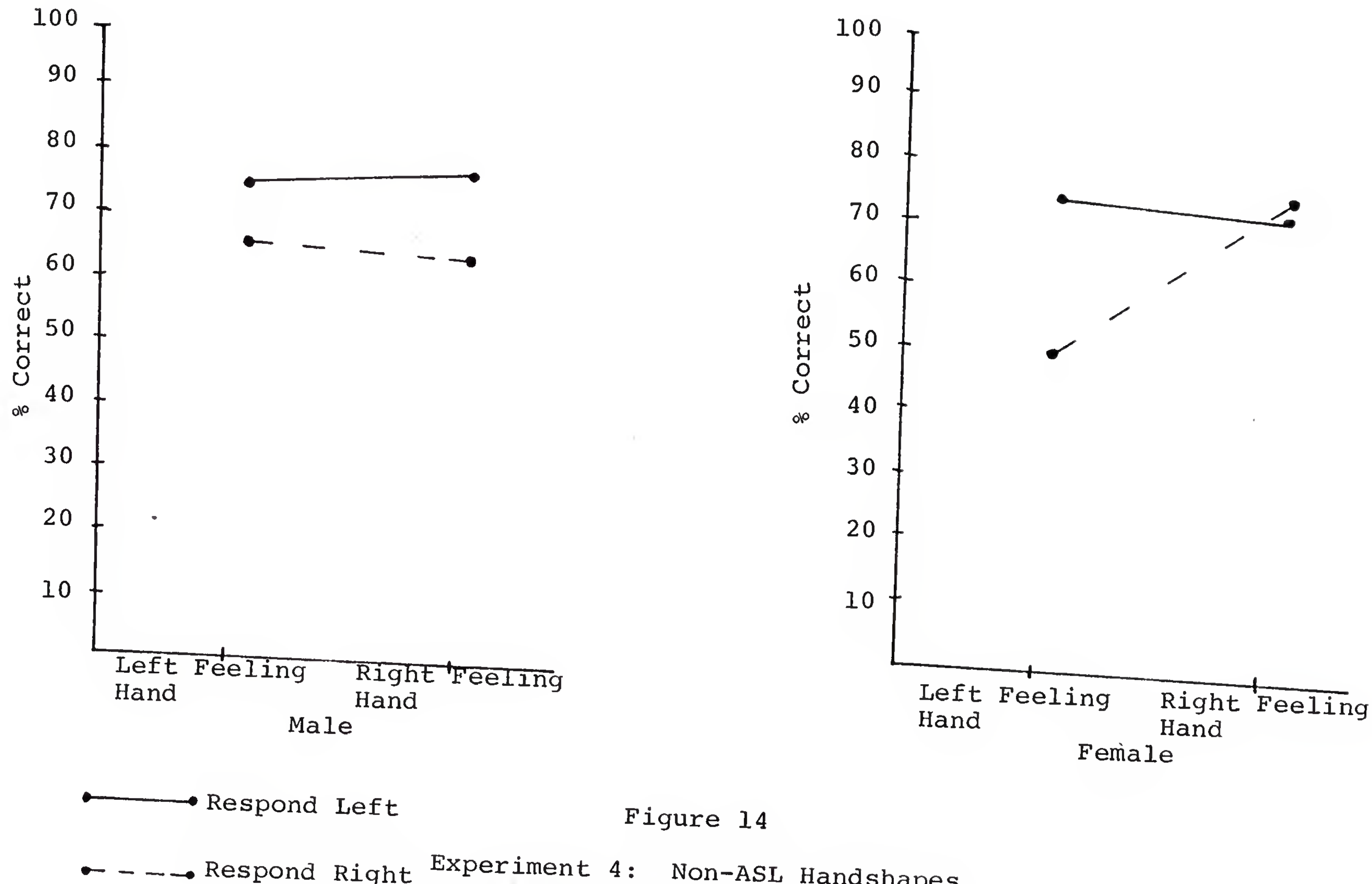



Figure 14

Experiment 4: Non-ASL Handshapes
Mean Percentage Correct
Feeling Hand x Response Hand x Sex

hemispheric conditions (X), i.e., input right field-output left hand and input left field-output right hand. Ranks of two and three were assigned to the second and third highest accuracy performance respectively. Tied ranks were assigned to individuals with equally good performance within conditions by task.

Assessing the performance of individual subjects across the tasks, no subjects demonstrated the same directional preference across all four tasks (i.e., no subjects received a ranking of one in either the LL, RR, or X condition for all four tasks). Of the total number of subjects, only four subjects demonstrated the same directional preference for three of the four tasks, while only 22 of the subjects showed a similar directional preference on two of the four tasks. Three separate Chi square analyses were then performed on the number of subjects showing superior performance on the LL, RR, and X conditions for each of the four tasks to determine if the Hearing, Oral and Sign group differed in their lateral directional preference. No significant differences were observed. Specifically, for the LL condition, $\chi^2 = 8.58$, df = 6, $p < .20$. The RR superior preference condition yielded a $\chi^2 = 8.84$, df = 6, $p < .20$. Finally, the crossed hemisphere condition yielded a $\chi^2 = 5.66$, df = 6, $p < .50$.

# CHAPTER IV
# DISCUSSION

## Group Effects

The major purpose of this research was to investigate the lateral organization of the brain in deaf individuals, particularly as this organization related to language. It was hoped that it might be possible to demonstrate differential laterality of processing language dependent on the deaf individual's early language training. To this extent, this research failed to find any significant differences in hemispheric organization between different deaf populations or between deaf and hearing populations. With the four separate experiments, there was never a group x field (either feeling hand or visual half-field) interaction effect, which would suggest differences in hemispheric organization. Experiment 1, which consisted of shape stimuli, particularly had been hypothesized to show differential effects of processing. Because no such effects were found, one must conclude that either there is no difference in the way the brain is lateralized for this task between the various groups, or that the task was not sensitive enough to enhance any difference that might exist. The same conclusions generally hold for the line orientation, ASL and

non-ASL tasks as well. The performance of the three groups on the tasks in the four experiments does not suggest that a different organization exists for any of the groups. Instead, in these experiments, with the demands of the four tasks, all groups were able to develop and use similar strategies (see Figure 15).

In addition, when the data was analyzed for direction of superior performance, i.e., better performance in the LL, RR, or X conditions, again no significant differences were obtained between the groups. Thus, whether one analyzed for level or for direction of preference, no significant differences were obtained between the groups. This finding weakens the argument that the groups showed differential lateral organization for language as predicted in the hypothesis. However, as noted earlier, it may be that the tasks themselves were insufficiently sensitive to demonstrate a language organization effect. Specifically, on the shape task in particular, allowing the subjects to wait 10 seconds before responding, which had been intended to pull for a verbal strategy, may have been too extended to guarantee that only a verbal strategy was employed. Further, by not specifically instructing the subjects to code the shapes verbally, it was possible that the subjects could have used something other than a verbal label to identify the shapes.

Group effects that did exist involved differential mean reaction times on Experiments 1 and 2 and differential mean

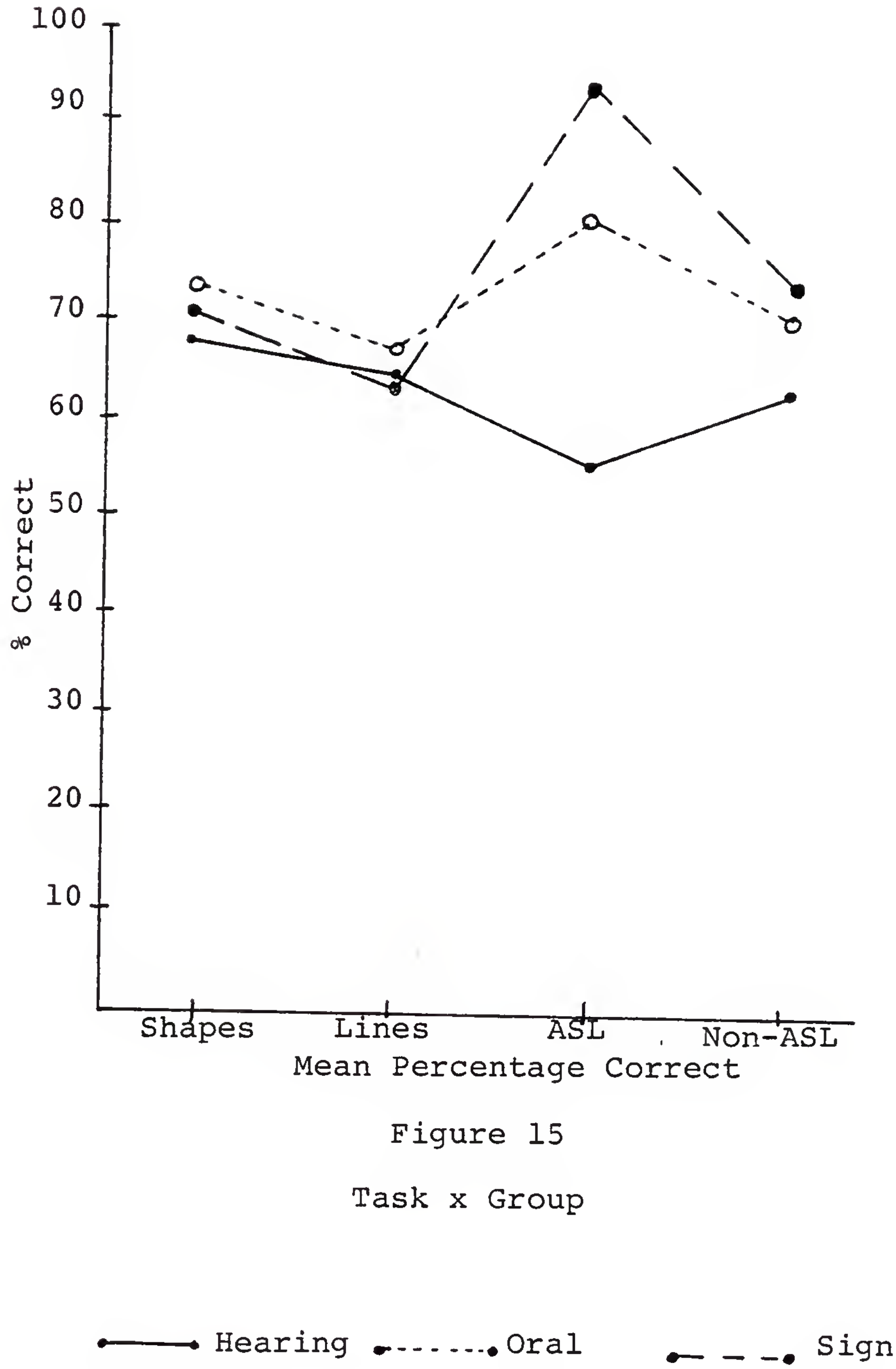



Figure 15

Task x Group

accuracy scores on Experiments 3 and 4. For Experiments 1 and 2 (shapes and lines) both deaf groups were significantly slower to respond than their hearing counterparts. No difference was evidenced between the reaction times of the three groups on the visual half-field tasks and while the hearing subjects responded more rapidly to the shapes and lines than to the visual half-field tasks, the deaf groups did not differ in speed of response across the four tasks. One possible explanation for this is that deaf individuals process information slower than hearing individuals and that even when the stimuli were familiar (as were the handshapes), is was not possible for the deaf subjects to process the information any more quickly. A more parsimonious explanation also exists, however, which avoids the necessity of invoking differences in brain processes between the deaf and hearing. This explanation would hold that differences in reaction times between deaf and hearing subjects reflect a motivational variable. Observing hearing subjects in the two tactile experiments, it was apparent that they were aware that they were being timed. Not only did they attempt to respond as rapidly as possible on these tasks, but they also evidenced concern at any point when the experimenter failed to stop the watch when they made their response (sometimes the experimenter would take a "split time" which allowed the watch to keep ticking). Deaf subjects, in

contrast, could not hear the watch (and the watch was not visible) so that they were generally less aware that they were being timed and did not strive for rapid responding. The behavior of the Hearing group was different for the visual half-field experiments. Here, because of the nature of the equipment and the timing device used, the stopwatch was not audible and subjects in all groups were generally unaware of being timed. In Experiments 3 and 4, there was no difference in reaction times for the three groups.

The other group effect occurred in Experiments 3 and 4 and involved differences in mean percentage correct for the visual handshapes for the three groups. The pattern of responding of the Hearing group for the non-ASL handshapes (response output from left hand superior to response output with right hand) suggests that these individuals processed these handshapes as "nonsense" visuospatial stimuli, evidencing a right hemispheric strategy. This pattern of visuospatial processing also existed for the deaf groups. Their experience with handshapes did seem to enhance their performance, however, such that they were generally more accurate than the Hearing group for the non-ASL handshapes. The two deaf groups did not differ between themselves in terms of accuracy for these stimuli ($\bar{x}$ Hearing = 63%, $\bar{x}$ Oral = 69%, $\bar{x}$ Sign = 72%). Reviewing results for the ASL handshapes, the Hearing group again appeared to process these handshapes as nonsense visuospatial stimuli with no

indications of differences in processing or accuracy ($\bar{x}$ Hearing = 56%). In addition, both deaf groups were again significantly more accurate than the Hearing group, but were also significantly more accurate than they were with the non-ASL handshapes, suggesting that the deaf groups viewed these signs as meaningful stimuli and processed them as language. Finally, not only were the two deaf groups more accurate for the ASL handshapes than for the non-ASL handshapes, but the Sign group was significantly more accurate than the Oral group for the ASL stimuli ($\bar{x}$ Oral = 80%; $\bar{x}$ Sign = 91%). The superior performance of the Sign group over the Oral group for the ASL handshapes adds validation to this research's separation of the deaf population according to early language training. In addition, these results suggest that early language training does affect the latter accuracy of processing sign language for deaf individuals.

## Hemispheric Organization Effects

Generally, while no major effects were observed for inferred hemispheric organization of language dependent on hearing status, laterality effects, reflecting differential hemispheric processing of different stimuli, were observed. The extent to which these effects were observed, however, was dependent on the type and nature of the task, and response used to assess laterality, and the sex of the individual. Usually,

type of task has been thought to determine laterality, but results of this research suggest that other parameters of the task, such as the inclusion of a memory component by adding a delay between stimuli presentation and response, may alter the demands of the task, thereby affecting laterality. Responses used to assess laterality, whether it be side of stimulus input (feeling hand; visual half-field) or side of response output (hand that makes the response) also affected laterality effects. Few researchers have thought to look at both stimuli input and response output, and therefore, their results are limited and may be misleading. Finally, while not predicted, sex was found to significantly interact with the type of task and the response variable measured (whether stimuli input or response output) to affect laterality results. Bullard, Satz, Harris, and Freund (1982) have reviewed the literature on sex effects in laterality research and note this dependence of laterality effects on the interaction of sex with task and type of response measured.

## Reaction Time

Generally, effects for the dependent variable mean reaction time were limited to the tactile experiments (shapes and lines) and did not evidence any laterality effects. Perhaps, one reason for this was that reaction time measured the time interval between stimulus presentation and first response, which tended to be fairly consistent. In contrast,

variability in terms of time between first and second response was much greater, often stretching out for a number of seconds and sometimes as much as 10, 20 or more seconds. The hesitancy in response for the second stimulus may reflect difficulty in inter-hemispheric crossover and therefore may be an important variable. One possible means to make reaction time a more sensitive measure of laterality effects therefore is to measure time of response for choice of first stimulus and time to response to second stimulus.

## Percentage Correct

Laterality effects for the dependent variable, mean percentage correct, were dependent on the type of task and will be discussed for each experiment separately.

Experiment 1: shapes. Initially, males were better than females at this task regardless of the side of input. This is consistent with Kimura's finding (1966) that females improve on visuospatial processing with time. In addition, it appeared that with time (and therefore, practice) response output with the right hand became more accurate. These effects demonstrate the importance of looking at both input and output if one is to make conclusions regarding laterality of hemispheres. If one had looked only at stimulus input for this task, a left hemisphere strategy would seem to dominate. Response output, in contrast, would argue for a right hemisphere strategy. Clearly, to understand what is occurring in the brain, one must consider both these variables.

What appears to have happened in this experiment is that shapes were initially (at time 1) handled using a visuo-spatial, right hemisphere strategy, as indicated by the superior performance of the left response hand, and that females improved with practice using this strategy. However, the design of the experiment pulled for a verbal strategy (by having the task be bilateral and including a memory component) and with practice a left hemisphere strategy did appear to develop, as evidenced by more accurate performance with the right response hand. Therefore, in this experiment, by including parameters to encourage verbal mediation, it was possible to override an initial right hemisphere strategy. This would suggest that it is possible to experimentally manipulate processing strategies, thereby altering strategies that might more typically be used. These findings are consistent with Bullard et al. (1982) who manipulated processing time between stimulus presentation and response (zero or 10-second delay) for complex shapes presented by visual half-fields and found that, while males used a right hemisphere strategy with no delay, they changed to a verbal strategy when delay was introduced. Gardner et al. (1977) is the only reported study to control for both stimulus input and response hand output, for the Witelson shapes. They found that the left feeling hand was generally superior, but that performances tended to be more accurate and faster when feeling hand and response hand were the same.

The Gardner et al. results are compatible with the current findings; however their experiment did not employ the memory component which may have lessened cross-hemispheric effects for the present study since it allowed more time for inter-hemispheric transfer of information.

Experiment 2: lines. Initially, tactile exploration of line orientations appeared to be a right hemisphere task. At time 1, feeling with the left hand was superior to feeling with the right; responding with the left was superior to responding with the right hand; and the feeling right-responding right condition (when input and output were both from the nondominant hemisphere) was significantly worse than all other conditions.

It was originally hypothesized that increasing the complexity of the task through bilateral presentation and invoking a memory component through the use of a delay should not override this right hemisphere strategy. However, with practice, males appeared able to develop a verbal strategy as they improved over time with input into the left hemisphere. In fact, while debriefing subjects after the experiment, many indicated that they had used verbal strategies, such as remembering the lines as the face of a clock, to facilitate memory. This is compatible with the Bullard et al. (1982) finding that males are more likely to use a right hemisphere strategy with visually presented line orientations when there is no delay between stimulus presentation and

response, but that they change to a verbal strategy when a delay is introduced.

Looking specifically at input to the hemisphere as separate from output, females showed significant improvement in right hemisphere processing of lines with time (time 1--feel left: $\bar{x}$ = 66%; time 2--feel left; $\bar{x}$ = 74%). This finding replicates the shape data, which also indicated that females improved in right hemisphere processing with time. For output with response hand, males appeared equally as accurate when responses were made with either hand, and were equally as accurate as females responding with the right hand. Females, however, despite gains made in accuracy across time with input to the right hemisphere, continued to do poorly when output was required from the right hemisphere. Breaking this sex x response hand interaction down across time, at time 1 males were more accurate when response output was from the right hemisphere (75% vs. 63%), as would be consistent with a right hemisphere, visuospatial strategy. Males, however, become more accurate with output from the left hemisphere by time 2 as a verbal strategy developed (respond right: 77%, respond left: 68%). Apparently, this increase in accuracy of output from the left hemisphere compromises right hemisphere strategy somewhat as evidenced by the lowered response accuracy for the left response hand for time 2 (respond left time 1: 75%, time 2: 68%). Females, in turn, were equally as accurate in output from either hemisphere at time

1 (respond left: 66%, respond right: 62%) and improved when output was from the left hemisphere at time 2 (respond right: 75%; respond left: 58%). These results are compatible with results for the shapes as graphs of the data for line orientations (Figures 3 and 4) are essentially no different from the graphs for Shapes (Figures 8 and 9).

Perhaps the major conclusion to be drawn from the results of this experiment pertains to the nature of the line orientation task. These results indicate that one cannot assume that line orientations are inherently a right hemispheric task. Instead, it appears that subjects have the capacity to invent and use a verbal strategy for line orientations, and will do so or not, depending on the demands of the task.

Experiment 3: ASL handshapes. No main effects for visual half-field were found for these stimuli. The group effects that were found (Sign>Oral Group) indicate that early language training does affect how the groups process these signs. The Hearing group treated these handshapes as nonsense visuospatial stimuli. Both deaf groups processed the ASL handshapes as meaningful, but the Sign group with early language training in ASL was significantly more accurate in processing the signs. With the exception of one study (Ross et al., 1979) researchers investigating language in deaf individuals have not considered or controlled early language training as a factor in the development of language for the

deaf. The differential responding in terms of accuracy of processing the ASL handshapes for the Oral and Sign group indicates that this factor should not be overlooked with investigating language in the deaf.

Experiment 4: Non-ASL handshapes. Inspection of the significant effects and interactions for the non-ASL handshapes suggests that all groups handled this as a primarily visuospatial task with response output from the right hemisphere being superior to response output from the left. In addition, males were generally more accurate for this task than were females. Poizner and Lane (1979), presenting these same stimuli unilaterally and without a delay between stimuli presentation and response, also found a right hemisphere advantage for both hearing and deaf subjects. However, the differences for hemisphere and sex in the present research (as shown by the visual half-field x sex x response hand interaction) were primarily due to the poor performance of the females when input was to the right hemisphere and output was from the left hemisphere. Apparently, while this task may be strongly lateralized to the right hemisphere because of its visuospatial nature, males could access this information fairly equally with either response hand (left: 72%; right: 68%) when stimuli were presented to the right hemisphere. Females, however, were only able to output efficiently when output was directed from the processing hemisphere. Crossed-hemisphere output was significantly poorer

for females (respond left: 75%; respond right: 46%). Gardner et al. (1977) found in their study that cross-hemispheric information retrieval decreased accuracy. These differences in the present research were not observed for the nondominant (left) hemisphere for the task. If females are less lateralized for visuospatial tasks, it may be that they pay the price in efficiency of output in a task that is strongly lateralized.

## Comparison of Present Findings with Past Research

Direct comparison of the present findings with previous research involving the hemispheric organization of deaf individuals is made difficult by explicit purposes of the present research. Specifically, early research into the lateral organization of language in deaf individuals limited the conclusions that might be drawn from this research by using tasks that did not represent language for deaf individuals (McKeever et al., 1976; Neville & Bellugi, 1978; Phippard, 1979); by choosing response sets that were too simple to invoke verbal mediation or favored one particular hemisphere over the other (Manning et al., 1977; Phippard, 1979; Poizner & Lane, 1979); and by failing to consider early language training within their deaf population (Manning et al., 1976; McKeever et al., 1977; Ross et al., 1979). The present research was designed to minimize these difficulties by

including a tactile modality to utilize another approach to attempt to tap language in the deaf; by increasing the complexity of the tasks through bilateral presentation; and by differentially assessing the performance of deaf individuals with early language training in a primarily oral or signing environment. Two additional factors, sex and response hand, which had been demonstrated to be of primary significance in work with hearing individuals (Bullard et al., 1982; Gardner et al., 1977; Harris et al., 1980) were also assessed.

Given these changes in the design of the present study, sex and the interaction of stimulus input and response output were demonstrated to be the most significant factors affecting laterality. In past research, sex of the individual subject has typically either been ignored (Gardner et al., 1977; Manning et al., 1977; Phippard, 1979), limited to one sex (McKeever et al., 1976), or information was gathered in such small or unequal proportions that the variable could not be assessed accurately (Cranney & Ashton, 1980; Poizner & Lane, 1979; Ross et al., 1979). Similarly, consideration of response hand (side of response output) has generally either been ignored (La Breche et al., 1977; Manning et al., 1977; McKeever et al., 1976; Oscar-Berman et al., 1978; Phippard, 1979; Ross et al., 1979); confined to the left or right hand (Cranney & Ashton, 1980; Witelson, 1974), or limited in the conclusions that could be drawn by the failure to use a bilateral task (Poizner & Lane, 1979).

Despite differences between the current study and these noted above, some general similarities in findings have emerged. For the Witelson's shapes task, La Breche et al. (1977) demonstrated a LHA for their hearing group and a trend toward a LHA for their deaf group, as measured by the hand of stimulus input. This is consistent with the present findings of a LHA for all groups on shapes as measured by side of stimulus input. As noted previously, however, response output in the present study suggested a right hemisphere strategy. Cranney and Ashton (1980), using a tactile paradigm with the Witelson shapes, failed to find a hemispheric advantage for either the deaf or hearing groups, but did not control for side of response output or for sex. The research with the Witelson shapes that is most consistent with the present findings is that of Gardner et al. (1977). Gardner et al. demonstrated a RHA for the shapes, consistent with the initial RHA for shapes in the present study. Because Gardner et al. did not utilize a delay component, however, they did not find as did the present study, the emergence of a left hemisphere, verbal strategy with continued exposure to the task. Most significant, however, was the finding by Gardner et al. of the importance of assessing both stimulus input and response output as the two variables were found to interact in determining laterality results. Furthermore, the present study did replicate the Gardner et al. finding that crossed hemispheric conditions were performed with less accuracy than uncrossed conditions.

The results of the line orientation task were most consistent with the literature, suggesting an initial right hemisphere strategy (Benton et al., 1973; Benton et al., 1978; Phippard, 1979). With time, however, the added memory component apparently facilitated the use of the left hemisphere (verbal) strategy. Although this change in strategy was not predicted, it was compatible with the results of Bullard et al. (1982) and with the shape data from Experiment 1. Thus, the present study demonstrated that initially, judgment of line orientations by hearing handicapped children is probably performed best by the right hemisphere. Extended exposure and familiarity with the task eventuates in the development of a left hemisphere (i.e., verbal) strategy for these children as it also does for normal hearing individuals (Bullard et al., 1982).

The results from the visual half-field experiments with the ASL and non-ASL handshapes were most compatible with the research by Poizner and Lane (1979). Both the present study and the work by Poizner and Lane demonstrated a clear RHA for the non-ASL handshapes for both the deaf and hearing subjects. Poizner and Lane, however, also demonstrated a RHA for all subjects to the ASL handshapes whereas in the present study no hemisphere advantage was observed for the ASL handshapes. Several differences in the two studies might contribute to these differential findings. First, Poizner and Lane utilized unilateral input, while in this study bilateral (i.e.,

competing) stimuli were used which increased the complexity of the task for the present subjects. Second, as discussed previously, the response measure for the present research may not have been sensitive enough to detect hemispheric differences. Poizner and Lane found in their results, that accuracy was not a sensitive measure of hemispheric differences. Instead, they relied on correct reaction time and combined this with a three second limitation to response time. Had these, or similar measures, been employed in the present study, a differential response by hemisphere might have been observed.

While past research has suggested the possibility that there may be a different organization of language for deaf individuals than for hearing, this was not observed in the present study. It was hoped that the use of two different deaf groups in comparison with a normal hearing control would demonstrate both the affect of the auditory system and the importance of early language training on the lateral organization of the brain, however, this was not demonstrated. While it is still an intriguing idea, results from the present study suggest several modifications that would be needed before any such differences might emerge. Included in these changes would be the induction of a verbal strategy set in all subjects on the shapes tasks by instructing the subjects to verbally code and remember the shapes; a shortening of the time to response or a measurement of time to both first and

second responses to limit or measure inter-hemispheric cross-over; and the use of both a delay and no delay condition to assess the effect of the memory component or processing strategy. However, the present study also makes clear the need for future research to take into account the importance of the sex of the subject and the interaction of stimulus input and response output in determining laterality, as failure to do so appears to lead to erroneous conclusions.

## Conclusions

The major finding of the present research, and one that was not predicted, was that differential effects for laterality exist dependent on sex. The predicted effect, differences in hemispheric processing of stimuli dependent on hearing status and early language training, was not found. While differential laterality effects for sex with different tasks were known to exist in the literature (Harris et al., 1980), it was thought that hearing status would overshadow the possible sex effects and therefore they were not predicted. Instead, what was observed was that sex effects interacting with type of task, side of stimulus input, and side of stimulus output overrode the consequences of being deaf. This would suggest that in terms of the way the brain is organized for certain types of tasks, it appears that it matters more whether you are male or female than whether you can hear or not. In effect, the present study ended up investigating

differences between the male and female brains, rather than between hearing and non-hearing individuals. Another major finding of the present study enforces the importance of considering both hemisphere input and hemisphere output when investigating differences in hemispheric organization of tasks. Failure to do so (which has more often been the rule rather than the exception with research in this area) could lead to erroneous conclusions regarding superiority of hemispheric output for tasks. Finally, this research supported the findings of Bullard et al. (1982) who noted that laterality effects are dependent on both type of task and strategy employed in performing the task. One should not assume that the presentation of certain stimuli alone insure a particular type of processing (i.e., verbal/nonverbal, analytic/visuospatial). Rather, the particular strategy used in a given task is a function of both the nature of the stimuli and the demands of the task. In addition, within a given task, the strategy employed may also vary as a function of exposure to and practice with the stimuli presented.

Future research with these different language populations might yield clearer results if the dependent measure used in the experiment is tightened. It was noted earlier that a change in the method of measuring reaction time by including a measure of the time to second stimulus chosen might prove a more sensitive measure of inter-hemispheric information retrieval. In addition, a similar effect might

be obtained for mean percentage correct by forcing the subjects to make their two choices within a set limited amount of time, thereby allowing less time for inter-hemispheric communication.

To further highlight the differences in hemispheric processing and the effect of processing strategy on laterality effects, a paradigm similar to the one used by Bullard et al. (1982) might be used. In this research, the authors not only compare side of stimulus input and side of response output, but also manipulate and compare processing strategies by investigating the effects of no delay versus a 10-second delay between stimulus presentation and response.

Finally, the inclusion of a verbal induction component which would instruct subjects to utilize a verbal labeling strategy in coding and remembering the shapes task might serve to lessen the chance that both deaf or hearing subjects would use other than a verbal processing strategy, thereby making the shape task a clearer measure of language laterality.

# APPENDIX

Table 2. Summary Table for Hearing, Oral and Sign Groups, Analysis of Variance for Mean Age.

| Source | df | Mean Square | *F* | *p* |
|---|---|---|---|---|
| Sex | 1 | 642,835 | 1.35 | .25 |
| Group | 2 | 4,452 | 0.01 | .99 |
| SG | 2 | 5,190 | 0.01 | .99 |
| Error | 51 | 475,062 | | |

Table 3. Summary Table for Hearing, Oral and Sign Groups, Analysis of Variance for Mean Intelligence Quotient.

| Source | df | Mean Square | *F* | *p* |
|---|---|---|---|---|
| Sex | 1 | 21,807 | 0.21 | .65 |
| Group | 2 | 174,607 | 1.66 | .20 |
| SG | 2 | 96,419 | 0.92 | .41 |

Table 4. Summary Table for Experiment 1: Analysis of Variance for Mean Percentage Correct.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | .688 | 6.11* |
| Group | 2 | .126 | 1.11 |
| SG | 2 | .215 | 1.91 |
| Error | 51 | .113 | |
| Feeling Hand | 1 | .012 | 0.34 |
| FS | 1 | .045 | 1.27 |
| FG | 2 | .106 | 2.97 |
| FSG | 2 | .019 | 0.53 |
| Error | 51 | .036 | |
| Time | 1 | .314 | 13.65*** |
| TS | 1 | .017 | 0.74 |
| TG | 2 | .014 | 0.61 |
| TSG | 2 | .045 | 1.97 |
| Error | 51 | .023 | |
| FT | 1 | .050 | 1.97 |
| FTS | 1 | .172 | 6.72* |
| FTG | 2 | .015 | 0.58 |
| FTGS | 2 | .018 | 0.70 |
| Error | 51 | .026 | |
| Response Hand | 1 | .197 | 8.09** |
| RS | 1 | .007 | 0.27 |
| RG | 2 | .065 | 2.66 |
| RSG | 2 | .005 | 0.20 |
| Error | 51 | .024 | |
| FR | 1 | .006 | 0.10 |
| FRS | 1 | .212 | 3.50 |
| FRG | 2 | .047 | 0.78 |
| FRSG | 2 | .016 | 0.26 |
| Error | 51 | .060 | |
| TR | 1 | .651 | 24.8*** |
| TRS | 1 | .018 | 0.67 |
| TRG | 2 | .004 | 0.16 |
| TRSG | 2 | .068 | 2.60 |
| Error | 51 | .026 | |

Table 4. Continued.

| Source | df | Mean Square | F |
|---|---|---|---|
| FTR | 1 | .099 | 1.99 |
| FTRS | 1 | .011 | 0.22 |
| FTRG | 2 | .054 | 1.09 |
| FTRSG | 2 | .045 | 0.90 |
| Error | 51 | .045 | |

Table 5. Summary Table for Experiment 1: Shapes Analysis of Variance for Mean Reaction Time.

| Source | df | Mean Square | _F_ |
|---|---|---|---|
| Sex | 1 | 12.476 | 1.66 |
| Group | 2 | 65.451 | 8.71*** |
| SG | 2 | 1.630 | 0.22 |
| Error | 51 | 7.518 | |
| Feeling Hand | 1 | .000 | 1.11 |
| FS | 1 | .000 | 0.41 |
| FG | 2 | .001 | 1.70 |
| FSG | 2 | .000 | 0.82 |
| Error | 51 | .000 | |
| Time | 1 | 11.122 | 9.86** |
| TS | 1 | .684 | 0.61 |
| TG | 2 | 4.020 | 3.56* |
| TSG | 2 | .135 | 0.12 |
| Error | 51 | 1.129 | |
| FT | 1 | .000 | 2.22 |
| FTS | 1 | .000 | 0.01 |
| FTG | 2 | .000 | 0.58 |
| FTSG | 2 | .000 | 1.63 |
| Error | 51 | .000 | |
| Response Hand | 1 | 3.587 | 2.32 |
| RS | 1 | .211 | 0.14 |
| RG | 2 | 1.129 | 0.73 |
| RSG | 2 | .864 | 0.56 |
| Error | 51 | 1.549 | |
| FR | 1 | .001 | 1.57 |
| FRS | 1 | .001 | 2.59 |
| FRG | 2 | .000 | 0.42 |
| FRSG | 2 | .000 | 0.86 |
| Error | 52 | .000 | |
| TR | 1 | 6.082 | 4.46* |
| TRS | 1 | 1.140 | 0.09 |
| TRG | 2 | 1.507 | 1.01 |
| TRSG | 2 | 1.045 | 0.70 |
| Error | 51 | 1.498 | |

Table 5. Continued.

| Source | df | Mean Square | $F$ |
|---|---|---|---|
| FTR | 1 | .000 | 1.79 |
| FTRS | 1 | .000 | 0.45 |
| FTRG | 2 | .000 | 0.80 |
| FTRSG | 2 | .000 | 1.43 |
| Error | 51 | .000 | |

Table 6. Summary Table for Experiment 2: Line Orientations Analysis of Variance for Mean Percentage Correct.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | .568 | 2.58 |
| Group | 2 | .022 | 0.21 |
| SG | 2 | .288 | 2.77 |
| Error | 51 | .104 | |
| Feeling Hand | 1 | .804 | 17.18*** |
| FS | 1 | .037 | 0.78 |
| FG | 2 | .016 | 0.35 |
| FSG | 2 | .019 | 0.43 |
| Error | 51 | 0.47 | |
| Time | 1 | .067 | 2.22 |
| TS | 1 | .000 | 0.00 |
| TG | 2 | .033 | 1.10 |
| TSG | 2 | .010 | 0.34 |
| Error | 51 | .030 | |
| FT | 1 | .003 | 0.13 |
| FTS | 1 | .266 | 11.19 |
| FTG | 2 | .004 | 0.16 |
| FTSG | 2 | .004 | 0.19 |
| Error | 51 | .024 | |
| Response Hand | 1 | .004 | 0.11 |
| RS | 1 | .131 | 4.23* |
| RG | 2 | .000 | 0.01 |
| RSG | 2 | .002 | 0.07 |
| Error | 51 | .031 | |
| FR | 1 | .078 | 1.99 |
| FRS | 1 | .025 | 0.64 |
| FRG | 2 | .017 | 0.43 |
| FRSG | 2 | .040 | 1.04 |
| Error | 51 | .039 | |
| TR | 1 | 1.740 | 61.83*** |
| TRS | 1 | .020 | 0.70 |
| TRG | 2 | .004 | 0.14 |
| TRSG | 2 | .025 | 0.89 |
| Error | 51 | .028 | |

Table 6. Continued.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| FTR | 1 | .917 | 22.96*** |
| FTRS | 1 | .011 | 0.26 |
| FTRG | 2 | .055 | 1.37 |
| FTRSG | 2 | .001 | 0.04 |
| Error | 51 | .040 | |

Table 7. Summary Table for Experiment 2: Line Orientations Analysis of Variance for Mean Reaction Time.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | 34.478 | 2.66 |
| Group | 2 | 84.759 | 6.54* |
| SG | 2 | 7.334 | 0.57 |
| Error | 51 | 12.965 | |
| Feeling Hand | 1 | .022 | 0.17 |
| FS | 1 | .018 | 1.59 |
| FG | 2 | .018 | 1.61 |
| FSG | 2 | .007 | 0.68 |
| Error | 51 | .011 | |
| Time | 1 | 4.244 | 8.07* |
| TS | 1 | .187 | 0.35 |
| TG | 2 | .804 | 1.53 |
| TSG | 2 | .682 | 1.30 |
| Error | 51 | .526 | |
| FT | 1 | .024 | 2.15 |
| FTS | 1 | .004 | 0.39 |
| FTG | 2 | .007 | 0.67 |
| FTSG | 2 | .014 | 1.25 |
| Error | 51 | .011 | |
| Response Hand | 1 | .920 | 1.43 |
| RS | 1 | .002 | 0.00 |
| RG | 2 | .769 | 1.20 |
| RSG | 2 | .217 | 0.34 |
| Error | 51 | .643 | |
| FR | 1 | .004 | 0.36 |
| FRS | 1 | .023 | 2.10 |
| FRG | 2 | .014 | 1.28 |
| FRGS | 2 | .007 | 0.67 |
| Error | 51 | .010 | |
| TR | 1 | .104 | 0.15 |
| TRS | 1 | .875 | 1.26 |
| TRG | 2 | .098 | 0.14 |
| TRSG | 2 | .304 | 0.44 |
| Error | 51 | .697 | |

Table 7. Continued.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| FTR | 1 | .018 | 1.64 |
| FTRS | 1 | .002 | 0.19 |
| FTRG | 2 | .007 | 0.68 |
| FTRSG | 2 | .017 | 1.58 |
| Error | 51 | .011 | |

Table 8. Summary Table for Experiment 3: ASL Handshapes Analysis of Variance for Mean Percentage Correct.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | .012 | 0.24 |
| Group | 2 | 2.449 | 49.03*** |
| SG | 2 | .086 | 1.71 |
| Error | 51 | .050 | |
| Visual Half-Field | 1 | .013 | 0.18 |
| Vs | 1 | .001 | 0.01 |
| Vg | 2 | .007 | 0.10 |
| Vsg | 2 | .007 | 0.10 |
| Error | 51 | .073 | |
| Response Hand | 1 | .020 | 1.06 |
| RS | 1 | .004 | 0.23 |
| RG | 2 | .038 | 1.99 |
| RSG | 2 | .044 | 2.30 |
| Error | 51 | .019 | |
| VR | 1 | .111 | 3.45 |
| VRS | 1 | .190 | 5.88* |
| VRG | 2 | .044 | 1.37 |
| VRSG | 2 | .021 | 1.65 |
| Error | 51 | .032 | 0.65 |

Table 9. Summary Table for Experiment 3: ASL Handshapes Analysis of Variance for Mean Reaction Time.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | 5.783 | 1.97 |
| Group | 2 | 1.284 | 0.44 |
| SG | 2 | 3.479 | 1.19 |
| Error | 51 | 2.932 | |
| Visual Half-Field | 1 | .070 | 1.27 |
| Vs | 1 | .057 | 1.04 |
| Vg | 2 | .067 | 1.21 |
| Vsg | 2 | .054 | 0.99 |
| Error | 51 | .055 | |
| Response Hand | 1 | 4.595 | 3.43 |
| RS | 1 | 1.148 | 0.86 |
| RG | 2 | .397 | 0.30 |
| RSG | 2 | .411 | 0.31 |
| Error | 51 | 1.340 | |
| VR | 1 | .059 | 1.07 |
| VRS | 1 | .059 | 1.07 |
| VRG | 2 | .062 | 1.13 |
| VRSG | 2 | .062 | 1.13 |
| Error | 51 | .055 | |

*$p<.05$
**$p<.01$
***$p<.001$

Table 10. Summary Table for Experiment 4: Non-ASL Handshapes Analysis of Variance for Mean Percentage Correct.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | .064 | 0.68 |
| Group | 2 | .154 | 1.64 |
| SG | 2 | .118 | 1.24 |
| Error | 51 | .094 | |
| Visual Half-Field | 1 | .136 | 3.50 |
| Vs | 1 | .120 | 3.10 |
| Vg | 2 | .056 | 1.44 |
| Vsg | 2 | .014 | 0.37 |
| Error | 51 | .039 | |
| Response Hand | 1 | .675 | 20.24*** |
| RS | 1 | .002 | 0.06 |
| RG | 2 | .023 | 0.68 |
| RSG | 2 | .008 | 0.25 |
| Error | 51 | .033 | |
| VR | 1 | .153 | 3.91* |
| VRS | 1 | .337 | 8.61* |
| VRG | 2 | .009 | 0.22 |
| VRSG | 2 | .023 | 0.60 |
| Error | 51 | .039 | |

*$p<.05$
**$p<.01$
***$p<.001$

Table 11. Summary Table for Experiment 4: Non-ASL Handshapes Analysis of Variance for Mean Reaction Time.

| Source | df | Mean Square | *F* |
|---|---|---|---|
| Sex | 1 | 2.598 | 0.61 |
| Group | 2 | 4.281 | 1.00 |
| SG | 2 | 5.864 | 1.37 |
| Error | 51 | 4.267 | |
| Visual Half-Field | 1 | 1.179 | 1.07 |
| VS | 1 | 1.179 | 1.07 |
| VG | 2 | 1.153 | 1.04 |
| VSG | 2 | 1.153 | 1.04 |
| Error | 51 | 1.104 | |
| Response Hand | 1 | .988 | 0.56 |
| RS | 1 | .012 | 0.01 |
| RG | 2 | 1.147 | 0.66 |
| RSG | 2 | 4.487 | 2.56 |
| Error | 51 | 1.751 | |
| VR | 1 | 1.312 | 1.20 |
| VRS | 1 | 1.312 | 1.20 |
| VRG | 2 | 1.285 | 1.18 |
| VRSG | 2 | 1.285 | 1.18 |
| Error | 51 | 1.089 | |

*$p<.05$
**$p<.01$
***$p<.001$

Table 12. Individual Subject's Rank Ordered Performance Within Conditions by Task.[1,2]

| | | | Shapes | | | Lines | | | ASL | | | non-ASL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Sex[3] | Group[4] | LL[5] | X | RR | LL | X | RR | LL | X | RR | LL | X | RR |
| 1 | M | S | 3 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 3 | 2 | 1 |
| 2 | M | S | 3 | 2 | 1 | 1 | 3 | 2 | 1 | 3 | 1 | 1 | 1 | 1 |
| 3 | M | S | 3 | 1 | 2 | 1 | 2 | 3 | 1 | 3 | 2 | 1 | 3 | 2 |
| 4 | M | S | 3 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 3 |
| 5 | M | S | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 3 | 1 | 3 | 2 | 1 |
| 6 | M | S | 3 | 2 | 1 | 1 | 2 | 3 | 3 | 1 | 2 | 1 | 1 | 3 |
| 7 | M | S | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 3 | 2 | 1 | 3 | 2 |
| 8 | M | S | 2 | 1 | 3 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 |
| 9 | M | S | 2 | 1 | 3 | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 1 |
| 10 | M | S | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 2 | 3 |
| 11 | F | S | 1 | 2 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 3 |
| 12 | F | S | 1 | 2 | 2 | 2 | 3 | 1 | 2 | 1 | 3 | 1 | 3 | 1 |
| 13 | F | S | 3 | 2 | 1 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 3 | 2 |
| 14 | F | S | 3 | 1 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 1 |
| 15 | F | S | 1 | 3 | 2 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| 16 | F | S | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 1 | 1 | 2 | 3 | 1 |
| 17 | F | S | 3 | 1 | 2 | 3 | 2 | 1 | 3 | 1 | 1 | 1 | 2 | 3 |
| 18 | F | S | 1 | 3 | 2 | 1 | 2 | 2 | 1 | 2 | 3 | 1 | 1 | 1 |
| 19 | F | S | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 1 | 2 | 2 | 1 | 2 |
| 20 | F | S | 1 | 3 | 2 | 2 | 1 | 3 | 1 | 1 | 1 | 1 | 3 | 2 |
| 21 | M | O | 1 | 3 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 3 |
| 22 | M | O | 1 | 3 | 2 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 3 | 2 |
| 23 | M | O | 1 | 2 | 3 | 3 | 2 | 1 | 3 | 2 | 1 | 1 | 2 | 3 |
| 24 | M | O | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 3 | 1 | 2 | 1 | 3 |
| 25 | M | O | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 3 | 1 | 2 |

[1] 1 = highest percentage correct within a task
2 = 2nd highest percentage correct within a task
3 = 3rd highest percentage correct within a task

[2] Tied ranks are equally good performance by condition.

[3] M = males; F = females

[4] O = Oral; S = Sign; H = Hearing

[5] LL = input left field-output left hand
X = combination of crossed hemispheric conditions (i.e., input left-output right and input right-output left).
RR = input right field-output right hand

Table 12. Continued.

| No. | Sex[3] | Group[4] | Shapes LL[5] | Shapes X | Shapes RR | Lines LL | Lines X | Lines RR | ASL LL | ASL X | ASL RR | non-ASL LL | non-ASL X | non-ASL RR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | M | O | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 3 |
| 27 | M | O | 1 | 2 | 3 | 2 | 1 | 3 | 2 | 2 | 1 | 3 | 2 | 1 |
| 28 | M | O | 2 | 1 | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 1 | 3 |
| 29 | M | O | 2 | 1 | 3 | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 30 | F | O | 2 | 1 | 3 | 1 | 2 | 3 | 3 | 1 | 1 | 1 | 3 | 2 |
| 31 | F | O | 3 | 2 | 1 | 1 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 |
| 32 | F | O | 3 | 2 | 1 | 1 | 3 | 2 | 3 | 1 | 2 | 3 | 2 | 1 |
| 33 | F | O | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 1 |
| 34 | F | O | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 2 | 3 | 1 | 3 | 1 |
| 35 | F | O | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 3 | 1 | 2 |
| 36 | F | O | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 3 | 1 | 2 | 3 | 1 |
| 37 | F | O | 3 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 3 |
| 38 | F | O | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 |
| 39 | M | H | 3 | 1 | 2 | 1 | 1 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 40 | M | H | 1 | 2 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 3 | 1 | 2 |
| 41 | M | H | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 3 | 1 | 1 | 2 | 3 |
| 42 | M | H | 1 | 2 | 2 | 2 | 1 | 3 | 3 | 2 | 1 | 2 | 3 | 1 |
| 43 | M | H | 3 | 1 | 2 | 1 | 1 | 3 | 2 | 3 | 1 | 2 | 1 | 2 |
| 44 | M | H | 2 | 1 | 3 | 2 | 3 | 1 | 1 | 1 | 3 | 2 | 1 | 3 |
| 45 | M | H | 1 | 1 | 3 | 3 | 1 | 2 | 2 | 3 | 1 | 2 | 1 | 3 |
| 46 | M | H | 2 | 3 | 1 | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 3 | 2 |
| 47 | M | H | 1 | 3 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 2 | 2 |
| 48 | F | H | 2 | 1 | 3 | 3 | 1 | 2 | 1 | 3 | 1 | 1 | 2 | 2 |
| 49 | F | H | 1 | 2 | 3 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 1 |
| 50 | F | H | 1 | 2 | 3 | 1 | 2 | 2 | 2 | 3 | 1 | 3 | 2 | 1 |
| 51 | F | H | 1 | 1 | 3 | 2 | 1 | 3 | 1 | 3 | 2 | 1 | 3 | 2 |
| 52 | F | H | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 1 | 3 | 2 |
| 53 | F | H | 3 | 1 | 2 | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 1 | 1 |
| 54 | F | H | 2 | 3 | 1 | 1 | 2 | 2 | 1 | 3 | 2 | 2 | 3 | 1 |
| 56 | F | H | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 2 | 3 | 3 | 1 | 1 |
| 57 | F | H | 2 | 3 | 1 | 1 | 1 | 3 | 1 | 2 | 3 | 1 | 1 | 1 |

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Eileen B. Fennell

Eileen B. Fennell, Chairman
Assistant Professor of Clinical Psychology

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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